

COMPRESSION FACTOR AND VAPOR LIQUID EQUILIBRIUM CALCULATIONS : CARBON DIOXIDE-HYDROCARBON SYSTEMS

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By
V. KARUPPASAMY

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It is certified that this work entitled
"Compression Factor and Vapor Liquid Equilibrium
Calculation: Carbon Dioxide-Hydrocarbon Mixtures"
has been carried out under my supervision and that
this has not been submitted elsewhere for a degree.

R. P. Singh

January 1982.

(Dr. R. P. Singh)
Assistant Professor
Department of Chemical Engineering
Indian Institute of Technology
KANPUR.

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<u>Mixtures</u>	<u>Composition</u>	<u>Temperature, °F</u>	<u>Pressure in psia</u>	<u>Page</u>
CO ₂ -Ethane	0.2	160, 220, 280, 340, 400, 460	200, 400, 600, 800, 1000, 1250, 1500, 1750, 2000, 2250	30
	0.6	100, 160, 220, 280, 340, 400, 460	200, 400, 600, 800, 1000, 1750, 2000	33
	0.8	160, 220, 280, 340, 400, 460	200, 400, 600, 800, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000	36
CO ₂ -Propane	0.2	220, 280, 340, 400, 460	200, 800, 1000, 1250	40
	0.4	220, 280, 340, 400, 460	200, 800, 1000, 1250	42
	0.8	160, 220, 280, 340, 400, 460	200, 400, 600, 800, 1000, 1250, 1500, 2000	44
CO ₂ -N-Butane	0.2	340, 400, 460,	200, 400, 600, 800, 1000	47
	0.5	340, 400, 460	200, 400, 600, 800, 1000, 1250, 1500	48
	0.7	340, 400, 460	200, 400, 600, 800, 1000, 1250, 1500	50

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3.	"	-25.0	300-700	5	54
4.	CO ₂ -Propane	-40.0	15.0-145.0	4	55
5.	"	-4.0	34.0-285.0	5	56
6.	"	11.8	35.28-283.710	12	57
7.	"	32.0	67.0-507.0	6	58
8.	"	32.0	69.090-505.680	12	59
9.	"	40.0	79.0-566.50	12	60
10.	"	70.0	125.0-860.90	17	61
11.	"	100.0	138.7-1002.50	19	62
12.	"	130.0	237.50-992.00	16	63
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NOMENCLATURE

ρ	Molar density
Z	Compression factor
Z_{LJ}	Compression factor, augmented with L.J. potential
N	Avagadro's number in Chapter 2
Z^{hs}	Compression factor for hard sphere molecule
σ	Hard sphere diameter, \AA
$u(r)$	Potential function
d	Equivalent hard sphere diameter
n	Number of Virial coefficients truncated for augmentation
B_2	Second Virial coefficient
B_3	Third Virial coefficient
B_m	Second Virial coefficient of the mixture
C_m	Third Virial coefficient of the mixture
ω	Accentric factor
T_r	Reduced temperature
N_i	Number of moles of component i
f_i	Fugacity of component i
x	molefraction
a_{ci}, b_{ci}, c_{ci} $a_i, b_i, c_i, \omega_i, \phi_i$	Pure component parameters for DWR equation
T	Temperature
P	Pressure
K_i	Equilibrium vaporization ratio of component i
ϵ	Characteristic energy

CHAPTER 1

INTRODUCTION

1.1. Literature Review

The separation of liquid or gaseous multicomponent mixtures into pure components or into fractions of desired composition is a common need of the chemical industry, e.g. in the preparation of mixture of raw materials for further processing and the purification of reaction products, etc. One of the essential requirements for rational design of units in separation operations like distillation, absorption, extraction etc. is a knowledge of the governing phase equilibria.

The possible number of liquid and vapor mixtures in technological processes is incredibly large and it is unreasonable to expect that experimental vapor liquid equilibria will ever be available for a significant fraction of this number. Furthermore, obtaining reliable and accurate experimental data requires an appreciable experimental skill and experience. It is, therefore, an economic necessity to consider techniques for calculating phase equilibria for multicomponent mixtures from few experimental data. Such techniques should require only a limited experimental effort and whenever possible, should be based on a theoretical foundation to provide reliability for interpolation and extrapolation with respect to temperature, pressure and composition.

Equations of state are usually used for predicting vapor-liquid equilibrium and volumetric properties in the absence of experimental data. Following van der Waals' work in 1873, many variations of the semi-empirical PVT equations have been proposed and these continuing efforts extended over more than a century and voluminous articles on this subject exist in the literature. The subject received fresh inputs with the advent of computers.

All existing equations are practical modifications of either the Virial equation or the Hard Core equation or both. Two major equations of state that still continue to be modified are the Redlich-Kwong (RK) and Benedict-Webb-Rubin (BWR) equation.

Redlich and Kwong⁽¹⁾ formulated a two parameter equation in 1949. Since then numerous modified RK equations have been proposed by Redlich and Dunlop⁽²⁾, Chue and Prausnitz⁽³⁾, Wilson⁽⁴⁾, Gadvitch and Joffe⁽⁵⁾ and numerous others. Chaudron and Renon⁽⁶⁾, Vogl and Hall⁽⁷⁾ considered the parameters as polynomials in the inverse reduced temperature and, by regressing experimental data for pure components, obtained constants for 25 substances. However, one recent modification of this equation made by Soave⁽⁸⁾, known as the Soave-Redlich-Kwong (SRK) equation, has rapidly gained acceptance by the hydrocarbon processing industry because of the relative simplicity of the equation. The most evident weakness of the SRK equation is that it is applicable only upto the critical temperature even for simple fluids.

The BWR equation⁽⁹⁾ is one of the most elaborate equations of state. It was originally developed by considering the properties of hydrocarbons and is traditionally associated with these compounds. However, this has been applied also to non-hydrocarbons. In general, the BWR equation will predict pressures that are within 0.5 per cent of the true values and densities upto 1.8 times the critical density. Major deviations exist at $T_r = 1.03$ and above a reduced pressure of 1.1. This is not unexpected since it is in the low temperature-high pressure region that the deficiencies of the BWR equation are more apparent.

Benedict et.al.⁽⁹⁾ demonstrated the ability of their equation to successfully predict phase equilibrium data for the Methane-Butane system at high temperatures. Few years later the same group extended the equation to low temperature predictions of pure component vapor pressures by defining the pure component coefficient as a function of temperature.

Scotter and Benedict⁽¹⁰⁾ further extended the BWR equation to predict hydrocarbon-nonhydrocarbon systems. They discovered that even though pure component vapor pressures were accurately predicted, the calculated phase equilibrium for mixtures of the same pure components showed significant errors. The inaccuracies were said to be due to the inability of the mixing rules to describe system nonidealities. The solution to this problem was to make A_0 in the mixing rule a function of the binary nonidealities. Their modification of

the mixing rule consisted of introducing a binary interaction coefficient k_{ij} , which was back calculated from experimental phase equilibrium data. In this manner, the phase equilibrium behavior of Nitrogen-Methane system were accurately predicted. Pomeroy and Alder⁽¹¹⁾, while working with natural gas systems, found that though predictions for wide boiling hydrocarbon-hydrocarbon mixtures could be accurately made at moderate and high temperatures, errors appeared at low temperatures. Their conclusion was that the mixing rules were the cause of these errors. Thus even for the prediction of a relatively close boiling system, Methane-Propane, at low temperatures, the original mixing rules were inadequate.

Orye⁽¹²⁾ successfully predicted phase equilibrium data for several wide boiling hydrocarbon-hydrocarbon and hydrocarbon-nonhydrocarbon systems by the modified mixing rule. For A. G. Stotler and Benedict⁽¹⁰⁾, and Guggenheim and Lee⁽²²⁾ applied the modified BWR equation to the experimental data of CO₂-Ethane system.

Joffe and Zudkevitch⁽⁵⁾ and Kaminishi et.al.⁽¹⁴⁾ noted that vapor liquid equilibrium relationships for systems containing CO₂ and light hydrocarbons could not be well correlated by using an equation of state. However, it has been pointed out^(14,15) that a marked improvement in these calculations are obtained by applying a modified BWR equation of state with the correction factor m corresponding to the interaction parameter.

A generalized BWR equation proposed by Starling and Han⁽¹⁶⁾, known as the BWRS equation, is able to predict the properties at reduced temperatures as low as $T_r = 0.3$ and reduced densities as high as $\rho_r = 3.0$. In this relation four coefficients are added to make it temperature sensitive. Later Michiue and Saito⁽¹⁷⁾ generalized the BWRS equation adding further four coefficients to predict thermodynamic properties at extremely low reduced temperatures, e.g., the vapor pressures of heavy hydrocarbons below a reduced temperature of 0.5.

1.2. Present Work

The present work involves calculation of vapor-liquid equilibria in binary systems of CO_2 with five light paraffins and Isobutane. The phase behavior of binary mixtures of CO_2 and light hydrocarbons has been investigated in some detail since the measurement of Kuenen in 1897, but there have been few vapor liquid equilibria studies in the low temperature range. Of more interest is the fact that these binaries do differ markedly in phase behavior from hydrocarbon systems because of the significant quadrupole moment of CO_2 as well as weak acid base complex formation with hydrocarbons.⁽¹⁸⁾ Comparison of experimental data with the modified RK equation^(19,20) provides a fairly good representation of the experimental data for each binary system. A modified BWR equation is also suitable for the study of CO_2 -hydrocarbon systems⁽¹²⁾ are of importance in secondary

recovery of petroleum reservoir fluids and in processing plants to remove solidified CO_2 either by absorption in amines or by molecular sieves.

The first part of the work applies the Augmented Benedict-Graves Equation of State⁽²¹⁾ in calculating compression factors at various temperature and pressures for binary mixtures of CO_2 and hydrocarbon.

The second part of the study involves vapor liquid equilibrium calculations for CO_2 -hydrocarbon binaries using the modified RWR equation of state.

CHAPTER 2

THEORY

2.1. Augmented Lennard-Jones (L-J) Equation of State

An equation of state is developed by combining L-J equation with a truncated Virial equation like the Augmented Hard Sphere equation developed by Bienkowski⁽²³⁾. The Augmented Hard Sphere equation is a combination of the Hard Sphere Equation (meant for high density) and Virial Equation (restricted to low density) in order that a systematic combination of the two may lead to a quantitative description of all the densities. With this augmenting procedure, the Augmented L-J equation of state is of the form:

$$\begin{aligned} Z^{LJA} &= \sum_{i=1}^{\infty} B_i^{LJ} \rho^{i-1} + \sum_{i=1}^n (B_i - B_i^{LJ}) \rho^{i-1} \\ &= Z^{LJ} + \sum_{i=1}^n (B_i - B_i^{LJ}) \rho^{i-1} \end{aligned} \quad (1)$$

2.2. Lennard-Jones Equation of State

Considering the perturbation theory studied by Barker and Henderson⁽²⁶⁾; Verlet and Weis⁽²⁷⁾ presented equation of state for L-J fluid. It has been approximated by hard sphere with a temperature dependent diameter. The interaction between the atoms for L-J potential is

$$\phi(r) = 4 \epsilon \left\{ \left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^6 \right\}$$

The equation of state for L.J. fluid proposed by Verlet and Weis is as follows:

$$\frac{P}{\rho kT} = \left(\frac{P}{\rho kT} \right)_{hs} + 8N\sigma^3 \phi_1(N\sigma^3) + 8^2(N\sigma^3)^2 \phi_2(N\sigma^3) \quad (2)$$

$$\text{where } \phi_1(N\sigma^3) = \sum_1^{\infty} b'_n(N\sigma^3)^n/n \quad (3)$$

$$\phi_2(N\sigma^3) = \sum_1^{\infty} c'_n(N\sigma^3)^n/n \quad (4)$$

Since molecular collisions become more energetic at higher temperatures, the interpenetration of the electronic clouds becomes deeper and hard core appears smaller. Barker and Henderson⁽²⁶⁾ suggested a rational definition of the hard core diameter d as a function of temperature given by:

$$d = \int_0^{\sigma} (1 - e^{-\beta u(r)}) dr \quad (5)$$

$$d = \int_0^{\sigma} \left\{ 1 - e^{-\frac{4}{\pi^*} \left\{ \left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^6 \right\}} \right\} dr \quad (6)$$

The equation proposed by Carnahan and Starling⁽²³⁾ is:

$$Z_{hs} = \frac{1 + n + n^2 - n^3}{(1 - n)^3} \quad (7)$$

$$\text{where } n = \frac{\pi}{6} N \rho \sigma^3, \quad T^* = KT/\epsilon$$

Using equations (3), (4), (6) and (7), the expansion in the power series about density, i.e., equation (2) reduces to:

$$\begin{aligned}
\frac{p}{RT} = Z^{LJ} = & 1 + \left(\frac{2}{3} \pi N d^3 + \beta b'_1 N d^3 \right) \rho + \left\{ 10 \left(\frac{\pi}{6} N d^3 \right)^2 + \right. \\
& \left. \beta b'_2 N^2 d^6 + \beta^2 c'_1 N^2 d^6 \right\} \rho^2 + \left\{ 18 \left(\frac{\pi}{6} N d^3 \right)^3 + \right. \\
& \left. 6^2 c'_2 (N d^3)^3 \right\} \rho^3 + \left\{ 28 \left(\frac{\pi}{6} N d^3 \right)^4 + \beta^2 c'_3 (N d^3)^4 \right\} \rho^4 + \\
& \left\{ 19 \left(\frac{\pi}{6} N d^3 \right)^5 + \beta b'_5 (N d^3)^5 \right\} \rho^5 + 5 \left(\frac{\pi}{6} N d^3 \right)^6 \rho^6 + \\
& \left\{ 15 \left(\frac{\pi}{6} N d^3 \right)^7 + \beta b'_7 (N d^3)^7 \right\} \rho^7 + \beta b'_{27} (N d^3)^{27} \rho^{27} + \\
& \beta^2 c'_{28} (N d^3)^{29} \rho^{29} \quad (8)
\end{aligned}$$

Here $\beta = \frac{1}{T^*}$

$b'_1 = -5.851$	$c'_1 = -1.27$
$b'_2 = -5.757$	$c'_2 = 7.438$
$b'_5 = 16.239$	$c'_3 = -8.938$
$b'_7 = -5.966$	$c'_{28} = 197.24$
$b'_{27} = -81.585$	

The augmented L.J. equation of state truncated after the third Virial coefficient is:

$$Z^{LJA} = Z^{LJ} + (B_2 - B_2^{LJ}) \rho + (B_3 - B_3^{LJ}) \rho^2 \quad (9)$$

From equation (8),

$$B_2^{LJ} = \frac{2}{3} \pi N d^3 + \beta b'_1 N d^3 \quad (10)$$

$$B_3^{LJ} = \left\{ 10 \left(\frac{\pi}{6} N d^3 \right)^2 + \beta b'_2 (N d^3)^2 + \beta^2 c'_1 (N d^3)^2 \right\} \quad (11)$$

Tsonopolous⁽²³⁾ modified the Pitzer and Curl relation for second Virial coefficient and the same is used to calculate the second Virial coefficient of CO₂ and light hydrocarbons. Tsonopolous correlation is given by:

$$\frac{B_2^P}{T_c} = f(0) + \omega f(1) \quad (12)$$

$$f(0) = 0.1445 - \frac{0.330}{T_r} - \frac{0.1385}{T_r^2} - \frac{0.0121}{T_r^3} - \frac{0.000607}{T_r^8} \quad (13)$$

$$f(1) = 0.0637 + \frac{0.331}{T_r^2} - \frac{0.423}{T_r^3} - \frac{0.008}{T_r^8} \quad (14)$$

Third Virial coefficients for Methane, Ethane and Propane is calculated by Pope's⁽²⁹⁾ generalized correlation for normal fluids given by:

$$\frac{C}{V_c^2} = C(0) + \omega C(1) + \omega^2 C(2) \quad (15)$$

$$C(0) = 107.08524180 - \frac{2444.3256915}{T_r} + \frac{53.469861915}{T_r^5} +$$

$$\{142.30301106 + \frac{2439.3332920}{T_r} - \frac{57.379328503}{T_r^5}\}$$

$$\exp(-\frac{T_r}{10}) + \{-1.8120154482 + \frac{1.1415112373}{T_r}\}$$

$$\{1 - \exp \frac{10}{T_r}\} 10^{-5} \quad (16)$$

$$C(1) = 7422.3669893 - \frac{166472.31956}{T_r} + \frac{2268.6104665}{T_r^5} +$$

$$(9475.01754 + \frac{166222.55809}{T_r} - \frac{2430.7825270}{T_r^5}) \exp(-\frac{T_r}{10})$$

$$+ (-5.5521375772 + \frac{3.3122093147}{T_r})(1 - \exp(\frac{T_r}{10}))10^{-4} \quad (17)$$

$$\begin{aligned} c^{(2)} = & -15528.405920 + \frac{1913444.1812}{T_r} - \frac{27377.947640}{T_r^5} \\ & + (-109521.89163 + \frac{1915413.3114}{T_r} + \frac{29542.360092}{T_r^5}) \\ & \exp(-\frac{T_r}{10}) + (0.00713119.38634 - \frac{0.0041948317443}{T_r}) \\ & (1 - \exp \frac{10}{T_r}) \end{aligned} \quad (18)$$

The Third Virial coefficient of CO_2 , n-Butane is calculated using the equation by Chueh⁽³⁰⁾:

$$\begin{aligned} \frac{C}{V_c^2} = & f_c(\frac{T}{T_c}, d) \\ f_c = & (0.332 T_r^{-0.25} + 0.468 T_r^{-5})(1 - \exp(1 - 1.89 T_r^2)) \\ & + d \exp(-(2.49 - 2.30 T_r + 2.70 T_r^2)) \end{aligned} \quad (19)$$

Few values of 'd' given are sufficient to suggest good estimation for other nonpolar gases. By a judicious interpolation, $d = 2$ for n-Butane and $d = 3$ for CO_2 has been chosen.

3.3. Extension to Mixtures

The augmented L.J. equation of state is extended to the binary mixtures of CO_2 and light hydrocarbons upto n-Butane for various compositions at different temperatures.

A significant result of the molecular theory of the Virial equation is the precise composition dependence of the mixture Virial coefficients. Second Virial coefficient is a quadratic function of the mole fraction.

$$B_m = \sum_{i=1}^m \sum_{j=1}^m y_i y_j B_{ij} \quad (20)$$

The third Virial coefficient is given by:

$$C_m = \sum_i^m \sum_j^m \sum_k^m y_i y_j y_k C_{ijk} \quad (21)$$

For a binary mixture:

$$B_m = y_1^2 B_1 + 2y_1 y_2 B_{12} + y_2^2 B_2 \quad (22)$$

$$C_m = y_1^3 C_1 + 3y_1^2 y_2 C_{112} + 3y_1 y_1^2 C_{122} + y_2^3 C_2 \quad (23)$$

The equation expresses that mixture Virial coefficients are made up of contributions due to molecular collisions of all sorts, and the weight of given kind is proportional to mole fractions of the components involved. Thus, the coefficients on the right hand side of the equation with indices all referring to the same component are just the Virial coefficients of the pure component. The indices are accordingly abbreviated like B_{11} to B_1 and C_{111} to C_1 etc.

In order to calculate the cross coefficients B_{ij} ($i \neq j$) we specify the parameters V_{cij} , T_{cij} , P_{cij} and ω_{ij} are as follows:

$$V_{cij} = \frac{1}{8} (V_{ci}^{1/3} + V_{cj}^{1/3})^3$$

$$T_{cij} = K_{ij} (T_{ci} T_{cj})^{1/2}$$

where K_{ij} is an adjustable binary parameter.

K_{ij} values are taken from the work of Plocker and Prausnitz⁽³⁴⁾. The interaction third Virial coefficient C_{ijk} is given by:

$$C_{ijk} = (C_{ij} C_{jk} C_{ik})^{1/3};$$

$$\text{where } C_{ij} = V_{cij}^2 f_c \left(\frac{T}{T_{cij}}, d_{ij} \right)$$

$$d_{ij} = \frac{1}{2} (d_i + d_j)$$

$$C_{112} = (C_{11} C_{13} C_{12})^{1/3}$$

$$C_{122} = (C_{12} C_{22} C_{12})^{1/3}$$

$$\omega_{ij} = \frac{1}{2} (\omega_i + \omega_j)$$

$$Z_{cij} = \frac{1}{2} (Z_{ci} + Z_{cj})$$

In order to find the potential parameter σ_x and ϵ_x for the mixtures, Gubbins⁽²⁵⁾ et al. proposed:

$$\epsilon_x \sigma_x^3 = \sum_{\alpha, \beta} x_\alpha x_\beta \epsilon_{\alpha, \beta} \sigma_{\alpha\beta}^3$$

$$\sigma_{\alpha\beta}^3 = \sum_{\alpha, \beta} x_{\alpha} x_{\beta} \sigma_{\alpha\beta}^3$$

With above mixture rules, the augmented L.J. equation of state for mixtures is written as follows:

$$Z_m^{LJA} = Z_m^{LJ} + (B_{2m} - B_{2m}^{LJ}) \rho + (B_{3m} - B_{3m}^{LJ}) \rho^2 \quad (24)$$

B_{2m} and B_{3m} are real fluid Virial coefficients for the mixture; B_{2m}^{LJ} and B_{3m}^{LJ} are calculated using equations (20) and (21) respectively.

2.4. Calculation of Fugacity Coefficient

The fugacity coefficient is derived from the augmented L.J. equation of state using the relation

$$\ln \phi = \int_{\infty}^V \left(\frac{1}{V} - \frac{P}{RT} \right) dV + Z - 1 - \ln Z \quad (25)$$

resulting in:

$$\begin{aligned} \ln \phi_m = & 2B_2 \rho + \frac{3}{2} B_3 \rho^2 + \frac{4}{3} B_4^{LJ} \rho^3 + \frac{5}{4} B_5^{LJ} \rho^4 + \frac{6}{5} B_6^{LJ} \rho^5 \\ & + 5 \cdot \frac{7}{6} \cdot B_7^{LJ} \rho^6 - \frac{8}{7} B_8^{LJ} \rho^7 + \frac{23}{27} B_{28}^{LJ} \rho^{27} \\ & + \frac{30}{29} B_{30}^{LJ} \rho^{29} - \ln Z^{LJA} \end{aligned} \quad (26)$$

The component fugacity coefficient is calculated using the relation:

$$RT \ln \phi_i = \int_{\infty}^V \left\{ \frac{RT}{V} - \left(\frac{P}{n_i T, v, n_j} \right) \right\} dV - RT \ln Z^{LJA} \quad (27)$$

resulting in:

$$\begin{aligned}
RT \ln \phi_i = & \{ B_{2m}' + 2B_{3m}' \rho + 3B_{4m}'^{LJ} \rho^2 + 5B_{6m}'^{LJ} \rho^4 \\
& + 30B_{7m}'^{LJ} \rho^6 - 105B_{8m}'^{LJ} \rho^7 + 27B_{28}'^{LJ} \rho^{27} \\
& + 29B_{30}'^{LJ} \rho^{29} \} - RT \ln Z^{LJA}
\end{aligned} \tag{28}$$

This relation can be applied to mixtures with appropriate selection of second and third Virial coefficients for the mixture.

VAPOR-LIQUID EQUILIBRIUM CALCULATION

The equation of state is:

$$P = \frac{RT}{V} + (B_0 RT - A_0 - \frac{C}{T^2}) \frac{1}{V^2} + (bRT - a) \frac{1}{V^3} + a \frac{1}{V^6} + \frac{C}{T^2} (1 + v_1 \frac{1}{V^2}) e^{-v_1 \frac{1}{V^2}} \quad (29)$$

Following the suggestion of Statler and Benedict⁽¹⁰⁾ the rule for A_0 has been modified as follows:

$$A_0 = \sum_i x_i^2 A_{oi} + \sum_i \sum_{\substack{j \\ j \neq i \\ j > i}} m_{ij} x_i x_j A_{oi}^{1/2} A_{oj}^{1/2} \quad (30)$$

Whereas in the original equation, m_{ij} is equal to 2, in the modified equation m_{ij} is the value determined from the equilibrium data.

The fugacity of a component in a multicomponent mixture is given by:

$$RT \ln f_i = \int_v^\infty \left\{ \left(\frac{\partial P}{\partial N_i} \right)_{T, V, N_j} - \frac{RT}{V} \right\} dV - RT \ln \frac{V}{N_i RT} \quad (31)$$

3.1. Original Mixing Rules

$$A_0 = \sum_i \sum_j x_i x_j A_{oi}^{1/2} A_{oj}^{1/2} \quad (32)$$

$$B_0 = \sum_i x_i B_{oi} \quad (33)$$

$$c_o = \left\{ \sum_i (x_i c_{oi}^{1/2}) \right\}^2 \quad (34)$$

$$b = \left\{ \sum_i (x_i b_i^{1/3}) \right\}^3 \quad (35)$$

$$a = \left\{ \sum_i (x_i a_i^{1/3}) \right\}^3 \quad (36)$$

$$e = \left\{ \sum_i (x_i e_i^{1/3}) \right\}^3 \quad (37)$$

$$\alpha = \left\{ \sum_i (x_i \alpha_i^{1/3}) \right\}^3 \quad (38)$$

$$v = \left\{ \sum_i (x_i v_i^{1/2}) \right\}^2 \quad (39)$$

3.3. Modified BWR Mixing Rule

$$A_o = \sum_i \sum_j x_i x_j A_{oi}^{1/2} A_{oj}^{1/2} (1 - k_{ij}) \quad (40)$$

The temperature dependence of the C_o coefficients is given in Table II⁽¹²⁾ and C_o has been correlated using the variable $\Delta T(T)$, where

$$\Delta C_o^{1/2}(T) = C_o^{1/2}(T_o) - C_o^{1/2}(T)$$

$C_o^{1/2}(T_o)$ is the high temperature value of $C_o^{1/2}$ given in Table I⁽¹²⁾. For temperatures above T_o , C_o is a constant.

For temperatures below T_o , the following equations are used for $\Delta C_o^{1/2}(T)$

$$\Delta C_o^{1/2}(T) = Q_1 \theta^2 + Q_2 \theta^3 + Q_3 \theta^4 + Q_4 \theta^5$$

where $\theta = \frac{T - T_o}{T_c}$; T is in °R.

Using the modified form of mixing rule

$$\begin{aligned}
 RT \ln \frac{f_i}{x_i} = & RT \ln \left(\frac{P}{P^0} \right) + (B_o + B_{oi})RT - 2(C_o C_{oi})^{1/2}/T^2 \\
 & - 2x_i A_{oi} - \sum_{j \neq i} x_j (A_{oi} A_{oj})^{1/2} \\
 & + \frac{3}{2} \{ (b^2 b_i)^{1/3} RT - (a^2 a_i)^{1/3} \} c^2 \\
 & + \frac{3}{5} \{ a(a^2 a_i)^{1/3} + \alpha (a^2 a_i)^{1/3} \} c^5 \\
 & + \frac{3}{T^2} (c^2 c_i)^{1/3} \left\{ \frac{1 - e^{-v_i^2}}{v_i^2} - \frac{e^{-v_i^2}}{2} \right\} \\
 & + \frac{2}{T^2} c \left(\frac{v_i}{v} \right)^{1/2} \left\{ \frac{1 - e^{-v_i^2}}{v_i^2} - e^{-v_i^2} \right. \\
 & \left. - \frac{v_i^2 e^{-v_i^2}}{v^2} \right\} \quad (41)
 \end{aligned}$$

where x_i may be either liquid or vapor mole fraction according to whether the density of the liquid or vapor is used.

At equilibrium, fugacities of each component i in all respective phases (V, L) are equal

$$f_i^V = f_i^L \quad \text{and by direct method,}$$

$$f_i^V = \phi_i^V y_i P$$

$$f_i^L = \phi_i^L x_i P$$

$$\text{and vaporisation ratio, } K_i = \frac{y_i}{x_i} = \frac{\phi_i^L}{\phi_i^V}$$

A bubble point program^(32,33) was written to satisfy the following conditions for binary systems at a specified temperature and liquid composition:

$$P(d^V, x_1) = P(d^L, x_1)$$

$$f_1(d^V, x_1) = f_1(d^L, x_1)$$

$$f_2(d^V, x_2) = f_2(d^L, x_2)$$

and

$$x_1 + x_2 = 1.0.$$

In every iteration step, the density of both liquid and vapor is calculated by substitution method of Johnson and Solover⁽³¹⁾.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. Augmented L.J. Equation of State

Compression factors calculated by augmented L.J. equation of state for three types of mixtures at different composition and temperatures studied are shown in Figures 1 to 7. In all the three types of mixtures, it gives reasonably good results upto 1000 psia and at moderate ranges of temperatures (upto 280°F). The deviation get larger for the values of pressures above 1000 psia as seen in Figures 1 and 2.

At high values of temperatures, i.e., above 280°F the results obtained are satisfactory. From the tabulated values, we can conclude that with high percentage of CO₂ in a typical CO₂-hydrocarbon mixture, the equation of state changes its trend from over-prediction to under-prediction.

Since Pope's generalized correlation (18) of third Virial coefficient is based purely on hydrocarbons, at high percentage of CO₂ in the mixture it is not able to give good results with the combination of Lennard-Jones potential. Improvements in the prediction can be made by adopting the equation proposed by Chueh (19) for CO₂-hydrocarbon systems.

4.3. Vapor-Liquid Equilibrium Calculation

The results obtained using bubble pressure program for various systems are tabulated. Application of DWR equation to both vapor and liquid is restricted by its binary parameter m_{ij} . The tabulated Benedict-Webb-Rubin constants (12) are not the best fit values to P-V-T data but are the adjusted parameters improving the generalized correlation for constants in the homologous series.

In this work, binary parameters for calculation are selected approximately so as it can cover the VLE data conditions. It was, therefore, not possible to get accurate values of both bubble pressure and vapor mole fraction.

Values of m_{ij} for certain systems as worked by Crye⁽¹²⁾ is taken as such and for the rest of the mixtures it is assumed to be equal to 2, i.e., we adopted the BWR equation with the original mixing rules.

Most of the results tabulated are the result above the binary parameter pressure range (by 2 or 3 data points) in order to find the nature of deviation. No definite conclusions can be reached unless proper values of m_{ij} are incorporated in the calculation.

Even though the calculated bubble pressure deviates much from the experimental value, the relative deviation for the equilibrium ratio is found to be smaller as evident from Figures 8 to 13. Figure 9 presents the results of calculation using the proper value of m_{ij} and a marked improvement is evident.

It has been recommended by Chueh and Prausnitz (I&EC Fundamentals 6, 492 (1967)) to use the $(1 - k_{ij})$ instead of v_{ij} . However due to the non-availability of the publication mentioned, we could not adopt that. It is felt that with the use of k_{ij} values and the mixing rules proposed by Hiraizumi and Saito⁽³⁵⁾ a marked improvement in the results can be achieved.

CHAPTER 5TABULATION OF PARAMETERS USED IN THIS WORKTABLE A: DIPOLE MOMENTS FOR THE L.S. (6, 12) POTENTIAL (3)

<u>Molecular Pair</u>	<u>σ Å</u>	<u>$\epsilon / K^{\circ}K$</u>
Methane	3.758	148.6
Ethane	4.443	215.7
Propane	5.118	237.10
Butane	4.687	309.74
CO ₂	3.941	195.2

TABLE P: PURE COMPONENT CONSTANTS USED IN THIS WORK

<u>Substance</u>	<u>T_c (°K)</u>	<u>P_c (atm)</u>	<u>V_c (cm³/gmole)</u>	<u>Z_c</u>	<u>ω</u>
Methane	190.6	45.4	99.0	0.288	0.008
Ethane	305.4	48.2	148.0	0.285	0.098
Propane	369.8	41.9	203.0	0.281	0.152
n-Butane	425.2	37.5	255.0	0.274	0.193
i-Butane	408.1	36.0	263.0	0.283	0.176
n-Pentane	469.6	33.3	304.0	0.262	0.251
n-Hexane	507.4	29.3	370.0	0.260	0.296
CO ₂	304.2	72.8	94.0	0.274	0.225

TABLE 8: BINARY INTERACTION PARAMETERS USED IN L.J. POTENTIAL MODEL⁽³⁴⁾

<u>System</u>	<u>K_{ij}</u>
CO ₂ -ethane	0.975
" -ethane	0.938
" -propane	0.925
" -butane	0.955
" -isobutane	0.946
" -n-pentane	1.002
" -n-hexane	1.018

TABLE 9: VALUE OF m_{ij} USED IN THIS WORK FOR VLE CALCULATION

<u>System</u>	<u>m_{ij}</u>
CO ₂ -ethane	1.800
" -propane	1.766
" -n-butane	1.720
" -isobutane	2.000
" -n-pentane	1.950
" -n-hexane	2.000

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CHAPTER 6TABULATION OF RESULTSTABLE 1: EQUIVALENT HARD SPHERE DIAMETER WITH RESPECT TO TEMPERATURE

ETHANE

<u>Temperature, °F</u>	<u>Hard Sphere Dia, Å</u>
100.0000	4.3656797
160.0000	4.3602681
220.0000	4.3551331
280.0000	4.3502445
340.0000	4.3455775
400.0000	4.3411108
460.0000	4.3368262

PROPANE

40.0000	5.0407505
100.0000	5.0344579
160.0000	5.0284986
220.0000	5.0228348
280.0000	5.0174352
340.0000	5.0122735
400.0000	5.0073275
460.0000	5.0025780

Contd....

TABLE 1 (continued)

N-BUTANE

<u>Temperature, °F</u>	<u>Hard Sphere Dia, Å</u>
100.0000	4.6447068
160.0000	4.6412199
220.0000	4.6378599
280.0000	4.6346162
340.0000	4.6314797
400.0000	4.6284422
460.0000	4.6254967

CARBON DIOXIDE

40.0000	3.8730368
100.0000	3.8677112
160.0000	3.8626859
220.0000	3.8579253
280.0000	3.8533999
340.0000	3.8490855
400.0000	3.8449614
460.0000	3.8410099

COMPRESSIBILITY FACTOR USING AGGREGATED LEARNED LOSS
 POTENTIAL FOR CO₂(1)-ETHANE(2) MIXTURE

TEMP F	ZMexpt1	ZML1	Z40JA 20dvir	Z40JA 3r3vir	Z40JA 60dV13V10 Z40JA
<hr/>					
Y1= 0.2000					
PRESSURE= 200.0Psia					
160.000	.9439	.9584	.9372	.9403	-0.379
220.000	.9571	.9704	.9546	.9567	-0.043
280.000	.9680	.9790	.9668	.9681	0.015
340.000	.9762	.9853	.9754	.9764	0.013
400.000	.9822	.9900	.9818	.9825	0.026
460.000	.9871	.9936	.9865	.9870	-0.007
Y1= 0.2000					
PRESSURE= 400.0Psia					
160.000	.8820	.9095	.8640	.8785	-0.399
220.000	.9128	.9373	.9041	.9131	0.035
280.000	.9360	.9563	.9309	.9368	0.083
340.000	.9529	.9696	.9496	.9535	0.065
400.000	.9652	.9797	.9630	.9657	0.056
460.000	.9749	.9871	.9729	.9749	-0.001
Y1= 0.2000					
PRESSURE= 600.0Psia					
160.000	.8158	.8514	.7775	.8157	-0.013
220.000	.8673	.9001	.8478	.8703	0.344
280.000	.9046	.9319	.8925	.9066	0.226
340.000	.9297	.9536	.9225	.9319	0.233
400.000	.9486	.9692	.9437	.9502	0.164
460.000	.9630	.9808	.9592	.9638	0.078

Y1= 0.2000

PRESSURE= 800.0Psia

160.000	.7395	.7804	.6717	.7543	1.035
220.000	.8217	.8592	.7456	.8301	1.018
280.000	.8730	.9061	.8517	.8706	0.843
340.000	.9077	.9371	.8946	.9120	0.876
400.000	.9329	.9588	.9212	.9301	0.339
460.000	.9522	.9746	.9455	.9539	0.176

Y1= 0.2000

PRESSURE=1000.0Psia

160.000	.6598	.6958	.5435	.7055	6.934
220.000	.7705	.8151	.7176	.7955	2.449
280.000	.8438	.8796	.8093	.8543	1.241
340.000	.8877	.9205	.8663	.8948	0.796
400.000	.9184	.9487	.9048	.9239	0.597
460.000	.9419	.9689	.9321	.9455	0.380

Y1= 0.2000

PRESSURE=1250.0Psia

160.000	.5708	.5879	.3680	.7062	23.716
220.000	.7245	.7589	.6284	.7682	6.030
280.000	.8093	.8467	.7551	.8315	2.746
340.000	.8645	.9008	.8311	.8760	1.560
400.000	.9023	.9370	.8811	.9120	1.080
460.000	.9306	.9627	.9161	.9375	0.742

Y1= 0.2000

PRESSURE=1500.0Psia

160.000	.5088	.5347	.2386	.8515	67.364
220.000	.6794	.7093	.5423	.7712	13.509
280.000	.7795	.8169	.7027	.8214	5.374
340.000	.8440	.8830	.7973	.8682	2.870
400.000	.8882	.9269	.8588	.9048	1.806
460.000	.9208	.9578	.9013	.9328	1.301

Y1= 0.2000

PRESSURE=1750.0Psi

160.000	.4897	.5812	.2253	1.1259	129.919
220.000	.6163	.6793	.4244	.8157	25.673
260.000	.7561	.7939	.6566	.3262	9.539
340.000	.8273	.8689	.7669	.6674	4.841
400.000	.8773	.9193	.8388	.9036	2.930
460.000	.9134	.9548	.8983	.9318	2.017

Y1= 0.2000

PRESSURE=2000.0Psi

160.000	.4971	.6967	.2926	1.4342	183.518
220.000	.6279	.6802	.4393	.9157	45.831
280.000	.7390	.7815	.6209	.6556	15.775
340.000	.8159	.8601	.7420	.8768	7.465
400.000	.8684	.9149	.8226	.9075	4.505
460.000	.9075	.9539	.8775	.9351	3.030

Y1= 0.2000

PRESSURE=2250.0Psi

160.000	.5183	.8263	.3903	1.7193	231.722
220.000	.6246	.7133	.4408	1.0501	68.131
280.000	.7279	.7830	.5996	.9057	24.425
340.000	.8080	.8579	.7237	.8977	11.106
400.000	.8631	.9145	.8093	.9189	6.464
460.000	.9043	.9558	.8695	.9429	4.264

Aver. Abs. Deviation, % = 15.5759

COMPRESSIBILITY FACTOR USING AUGMENTED TEMPERATURE
POTENTIAL FOR CO₂(1)-ETHANE(2) MIXTURE

TEMPERATURE Z_{MIXTURE} Z_{M1} Z_{01JA} Z_{01JA} Z_{01JA}
2nd vir 3rd vir 4th vir

X1= 0.6000

PRESSURE= 200.00psia

100.000	.9370	.9611	.9277	.9301	-0.734
160.000	.9542	.9735	.9499	.9515	-0.279
220.000	.9661	.9821	.9645	.9657	-0.039
280.000	.9749	.9882	.9746	.9754	0.055
340.000	.9814	.9926	.9817	.9823	0.094
400.000	.9865	.9959	.9863	.9873	0.085
460.000	.9905	.9983	.9907	.9911	0.057

Y1= 0.6000

PRESSURE= 400.00psia

100.000	.8645	.9142	.8418	.8533	-1.294
160.000	.9060	.9436	.8939	.9010	-0.548
220.000	.9315	.9626	.9262	.9313	-0.022
280.000	.9500	.9757	.9478	.9515	0.155
340.000	.9635	.9850	.9628	.9655	0.205
400.000	.9735	.9918	.9735	.9755	0.209
460.000	.9812	.9968	.9814	.9829	0.178

Y1= 0.6000

PRESSURE= 600.00psia

100.000	.7794	.8554	.7350	.7669	-1.608
160.000	.8543	.9097	.8306	.8487	-0.661
220.000	.8960	.9416	.8848	.8972	-0.132

280.000	.9246	.9626	.9197	.9284	0.416
340.000	.9158	.9773	.9434	.9497	0.416
400.000	.9606	.9878	.9601	.9648	0.433
460.000	.9725	.9956	.9723	.9758	0.336

Y1= 0.6000

PRESSURE= 800.0Psia

100.000	.6785	.7779	.5935	.6682	-1.518
160.000	.7997	.8713	.7587	.7953	-0.554
220.000	.8604	.9192	.8404	.8642	0.445
280.000	.9000	.9493	.8904	.9069	0.771
340.000	.9284	.9698	.9237	.9354	0.754
400.000	.9488	.9842	.9467	.9553	0.681
460.000	.9643	.9947	.9633	.9697	0.556

Y1= 0.6000

PRESSURE=1000.0Psia

100.000	.5575	.6714	.3909	.5637	1.117
160.000	.7422	.8284	.6766	.7431	0.116
220.000	.8257	.8959	.7933	.8337	0.974
280.000	.8767	.9361	.8605	.8877	1.250
340.000	.9122	.9626	.9039	.9229	1.173
400.000	.9373	.9810	.9336	.9472	1.059
460.000	.9563	.9942	.9547	.9648	0.884

Y1= 0.6000

PRESSURE=1250.0Psia

100.000	.3852	.5660	.0585	.6243	62.066
160.000	.6697	.7712	.5610	.6885	2.810
220.000	.7830	.8667	.7315	.8018	2.396
280.000	.8487	.9202	.8226	.8679	2.260
340.000	.8935	.9544	.8796	.9105	1.903
400.000	.9242	.9778	.9177	.9396	1.671
460.000	.9476	.9944	.9445	.9606	1.367

Y1= 0.6000

PRESSURE=1500.0Psia

100.000	.3449	.7992	.1191	1.1353	229.164
160.000	.6031	.7227	.4427	.6690	10.927
220.000	.7444	.8404	.6696	.7816	5.004
280.000	.8240	.9063	.7857	.8548	3.743
340.000	.8767	.9478	.8563	.9025	2.946
400.000	.9126	.9759	.9028	.9353	2.482
460.000	.9400	.9957	.9353	.9588	1.995

Y1= 0.6000

PRESSURE=1750.0Psia

100.000	.3621	1.0498	.2940	1.5489	327.747
160.000	.5529	.7108	.3544	.7210	30.397
220.000	.7113	.8213	.6128	.7799	9.628
280.000	.8024	.8958	.7513	.8506	6.007
340.000	.8621	.9434	.8348	.8990	4.387
400.000	.9035	.9756	.8895	.9345	3.434
460.000	.9333	.9982	.9273	.9596	2.821

Y1= 0.6000

PRESSURE=2000.0Psia

100.000	.3899	1.2626	.4604	1.8740	380.640
160.000	.5278	.7582	.3315	.8569	62.349
220.000	.6849	.8150	.5675	.8028	17.209
280.000	.7843	.8905	.7216	.8573	9.308
340.000	.8494	.9420	.8160	.9036	6.383
400.000	.8953	.9773	.8780	.9379	4.750
460.000	.9280	1.0022	.9207	.9634	3.818

Aver. Abs. Deviation, % = 19.3561

COMPRESSIBILITY FACTOR USING AUGMENTED LENNARD JONES
POTENTIAL FOR CO₂(1)-ETHANE(2) MIXTURE

TEMP F	ZMexp1	ZMLJ	ZMLJA 2ndvir	ZMLJA 3rdvir	%DEVIATION Z ^{MLJA}
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Y1= 0.8000

PRESSURE= 200.0Psia

160.000	.9562	.9770	.9334	.9345	-2.267
220.000	.9680	.9846	.9532	.9541	-1.435
280.000	.9774	.9900	.9667	.9675	-1.015
340.000	.9833	.9940	.9762	.9769	-0.655
400.000	.9880	.9969	.9831	.9837	-0.440
460.000	.9917	.9991	.9883	.9887	-0.394

Y1= 0.8000

PRESSURE= 400.0Psia

160.000	.9108	.9512	.8598	.8645	-5.080
220.000	.9358	.9680	.9029	.9070	-3.080
280.000	.9543	.9796	.9318	.9351	-2.011
340.000	.9670	.9878	.9517	.9544	-1.302
400.000	.9766	.9938	.9660	.9682	-0.965
460.000	.9835	.9983	.9765	.9782	-0.538

Y1= 0.8000

PRESSURE= 600.0Psia

160.000	.8623	.9222	.7773	.7893	-8.464
220.000	.9022	.9502	.8490	.8587	-4.821
280.000	.9311	.9688	.8953	.9031	-3.002
340.000	.9508	.9817	.9266	.9329	-1.887
400.000	.9651	.9909	.9488	.9536	-1.187
460.000	.9756	.9978	.9649	.9687	-0.709

Y1= 0.8000

PRESSURE= 800.0Psia

160.000	.8123	.8898	.6848	.7088	-12.746
220.000	.8686	.9313	.7911	.8098	-6.769
280.000	.9085	.9578	.8573	.8720	-4.014
340.000	.9343	.9756	.9010	.9124	-2.341
400.000	.9534	.9883	.9314	.9403	-1.377
460.000	.9681	.9976	.9533	.9602	-0.813

Y1= 0.8000

PRESSURE=1000.0Psia

160.000	.7576	.8535	.5787	.6218	-17.927
220.000	.8361	.9117	.7297	.7612	-8.957
280.000	.8858	.9468	.8180	.8422	-4.927
340.000	.9189	.9699	.8750	.8935	-2.762
400.000	.9431	.9861	.9141	.9283	-1.569
460.000	.9609	.9977	.9420	.9530	-0.827

Y1= 0.8000

PRESSURE=1250.0Psia

160.000	.6883	.8045	.4264	.5080	-26.192
220.000	.7960	.8870	.6480	.7024	-11.759
280.000	.8588	.9335	.7675	.8077	-5.953
340.000	.9002	.9634	.8423	.8725	-3.080
400.000	.9305	.9840	.8928	.9156	-1.605
460.000	.9524	.9985	.9283	.9457	-0.703

Y1= 0.8000

PRESSURE=1500.0Psia

160.000	.6203	.7585	.2550	.3997	-35.556
220.000	.7568	.8638	.5621	.6488	-14.272
280.000	.8335	.9217	.7164	.7778	-6.681

340.000	.8833	.9582	.8100	.8551	-3.187
400.000	.9193	.9829	.8722	.9057	-1.478
460.000	.9448	1.0003	.9153	.9407	-0.429

Y1= 0.8000

PRESSURE=1750.0Psia

160.000	.5597	.7357	.0847	.3266	-41.639
220.000	.7214	.8454	.4762	.6060	-15.997
280.000	.8108	.9124	.6662	.7545	-6.943
340.000	.8678	.9546	.7787	.8423	-2.936
400.000	.9087	.9831	.8524	.8992	-1.050
460.000	.9380	1.0030	.9032	.9383	0.034

Y1= 0.8000

PRESSURE=2000.0Psia

160.000	.5221	.7654	-.0321	.3310	-36.596
220.000	.6909	.8363	.3957	.5805	-15.973
280.000	.7914	.9070	.6187	.7398	-6.527
340.000	.8541	.9534	.7491	.8349	-2.246
400.000	.8992	.9849	.8340	.8964	-0.316
460.000	.9318	1.0070	.8921	.9387	0.736

Y1= 0.8000

PRESSURE=2250.0Psia

160.000	.5068	.8524	-.0719	.4158	-17.957
220.000	.6684	.8414	.3291	.5790	-13.371
280.000	.7746	.9069	.5756	.7356	-5.040
340.000	.8429	.9552	.7223	.8338	-1.083
400.000	.8918	.9887	.8175	.8977	0.665
460.000	.9264	1.0124	.8824	.9420	1.684

Y1= 0.8000

PRESSURE=2500.0Psia

160.000	.5082	.9741	-.0501	.5488	7.987
220.000	.6522	.8649	.2814	.6056	-7.150

280.000	.7621	.9137	.5395	.7435	-2.437
340.000	.8343	.9605	.6991	.8395	0.627
400.000	.8853	.9947	.8031	.9036	2.072
460.000	.9227	1.0194	.8744	.9485	2.797

Y1= 0.8000

PRESSURE=2750.0Psia

160.000	.5194	1.1097	.0074	.7011	34.979
220.000	.6447	.9071	.2579	.6593	2.261
280.000	.7531	.9285	.5120	.7648	1.551
340.000	.8280	.9698	.6801	.8527	2.981
400.000	.8811	1.0032	.7915	.9143	3.766
460.000	.9200	1.0281	.8681	.9583	4.168

Y1= 0.8000

PRESSURE=3000.0Psia

160.000	.5373	1.2421	.0796	.8511	58.101
220.000	.6445	.9658	.2573	.7353	14.090
280.000	.7487	.9517	.4947	.7991	6.725
340.000	.8236	.9839	.6661	.8737	6.079
400.000	.8792	1.0144	.7829	.9297	5.741
460.000	.9192	1.0386	.8639	.9715	5.687

Aver. Abs. Deviation, % = 7.1188

COMPRESSIBILITY FACTOR USING AUGMENTED LENNARD JONES
POTENTIAL FOR CO₂(1)-PROPANE(2) MIXTURE

TEMP F	Z _{hexpt1}	Z _{MLJ}	Z _{MLJA} 2ndVir	Z _{MLJA} 3rdVir	%DEVIATION Z _{MLJA}
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Y1= 0.2000

PRESSURE= 200.0Psia

220.000	.9123	.9544	.9129	.9183	0.654
280.000	.9348	.9681	.9361	.9396	0.514
340.000	.9508	.9778	.9522	.9545	0.391
400.000	.9616	.9849	.9637	.9653	0.385
460.000	.9711	.9903	.9723	.9734	0.236

Y1= 0.2000

PRESSURE= 800.0Psia

220.000	.5305	.7071	.4218	.6744	27.125
280.000	.7120	.8373	.6696	.7656	7.530
340.000	.7985	.8986	.7767	.8294	3.865

400.000	.8514	.9363	.8405	.8729	2.526
460.000	.8986	.9621	.8834	.9044	1.783

Y1= 0.2000

PRESSURE=1000.0Psia

220.000	.4162	.6893	.2347	.8758	110.439
280.000	.6347	.7915	.5563	.7451	17.392
340.000	.7485	.8731	.7105	.8042	7.440
400.000	.8180	.9224	.7978	.8526	4.229
460.000	.8659	.9553	.8543	.8890	2.670

Y1= 0.2000

PRESSURE=1250.0Psia

220.000	.3715	1.0693	.4327	1.6900	354.925
280.000	.5695	.7783	.4507	.8170	43.467
340.000	.6944	.8538	.6348	.8048	15.904
400.000	.7805	.9115	.7483	.8424	7.925
460.000	.8410	.9512	.8213	.8787	4.484

Aver. Abs. Deviation, % = 30.6941

COMPRESSIBILITY FACTOR USING AUGMENTED LENNARD JONES
POTENTIAL FOR CO2(1)-PROPANE(2) MIXTURE

TEMP F	ZM _{exptl}	ZMLJ	ZMLJA 2ndVir	ZMLJA 3rdVir	%DEVIATION ZMLJA
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Y1= 0.4000

PRESSURE= 200.0Psf

160.000	.9069	.9488	.9189	.9242	1.907
220.000	.9349	.9646	.9423	.9458	1.165
280.000	.9508	.9754	.9577	.9601	0.974
340.000	.9635	.9832	.9686	.9702	0.691
400.000	.9715	.9889	.9764	.9775	0.615
460.000	.9789	.9932	.9822	.9830	0.416

Y1= 0.4000

PRESSURE= 800.0Psf

160.000	.7998	.7628	.6270	.7360	-7.981
220.000	.6976	.8110	.6915	.7914	13.445
280.000	.7945	.8837	.7993	.8529	7.346
340.000	.8544	.9265	.8607	.8931	4.531
400.000	.8912	.9545	.8999	.9210	2.346
460.000	.9198	.9743	.9273	.9416	2.367

Y1= 0.4000

PRESSURE=1000.0Psia

160.000	.6658	.6586	.4546	.7004	5.201
220.000	.6165	.7489	.5799	.7797	26.480
280.000	.7445	.8509	.7383	.8336	11.965
340.000	.8195	.9079	.8272	.8773	7.051
400.000	.8669	.9444	.8742	.9091	4.873
460.000	.9025	.9697	.9098	.9330	3.376

Y1= 0.4000

PRESSURE=1250.0Psia

160.000	.4850	.5915	.2414	.9652	99.012
220.000	.5195	.7122	.4615	.9014	73.508
280.000	.6883	.8179	.6656	.8398	22.012
340.000	.7800	.8890	.7764	.8714	11.723
400.000	.8408	.9349	.8445	.9025	7.336
460.000	.8850	.9664	.8900	.9276	4.810

 Aver. Abs. Deviation, % = 13.4224

COMPRESSIBILITY FACTOR USING AUGMENTED LENNARD JONES
POTENTIAL FOR CO₂(1)-PROPANE(2) MIXTURE

TEMP F	ZMe _{vdw} 1	ZMLJ	ZMLJA 2ndVir	ZMLJA 3rdVir	%DEVIATION ZMLJA
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19.

Y1= 0.8000

PRESSURE= 200.0 psia

160.000	.9485	.9715	.9296	.9313	-1.818
220.000	.9638	.9807	.9506	.9519	-1.234
280.000	.9735	.9871	.9648	.9658	-0.789
340.000	.9800	.9918	.9748	.9756	-0.451
400.000	.9853	.9953	.9820	.9827	-0.269
460.000	.9895	.9979	.9874	.9879	-0.163

Y1= 0.8000

PRESSURE= 400.0 psia

160.000	.8920	.9387	.8496	.8569	-3.930
220.000	.9253	.9595	.8968	.9025	-2.463
280.000	.9468	.9735	.9275	.9320	-1.565
340.000	.9610	.9834	.9486	.9521	-0.930
400.000	.9709	.9906	.9637	.9663	-0.472
460.000	.9799	.9960	.9747	.9769	-0.317

Y1= 0.8000

PRESSURE= 600.0 psia

160.000	.8301	.9004	.7569	.7759	-6.528
220.000	.8860	.9364	.8382	.8522	-3.812
280.000	.9190	.9592	.8881	.8988	-2.196
340.000	.9419	.9749	.9216	.9297	-1.290
400.000	.9574	.9861	.9451	.9512	-0.643
460.000	.9698	.9944	.9621	.9668	-0.306

Y1= 0.8000

PRESSURE= 800.0Psia

160.000	.7635	.8558	.6477	.6876	-0.938
220.000	.8439	.9113	.7738	.8014	-5.037
280.000	.8925	.9445	.8469	.8671	-2.844
340.000	.9231	.9665	.8940	.9090	-1.524
400.000	.9439	.9819	.9264	.9377	-0.660
460.000	.9597	.9932	.9497	.9582	-0.157

Y1= 0.8000

PRESSURE=1000.0Psia

160.000	.6910	.8038	.5165	.5926	-14.237
220.000	.8022	.8849	.7042	.7518	-6.283
280.000	.8639	.9296	.8036	.8373	-3.083
340.000	.9045	.9584	.8660	.8904	-1.560
400.000	.9310	.9782	.9078	.9259	-0.548
460.000	.9500	.9924	.9374	.9511	0.111

Y1= 0.8000

PRESSURE=1250.0Psia

160.000	.5976	.7345	.3192	.4783	-19.968
220.000	.7484	.8514	.6091	.6947	-7.181
280.000	.8270	.9116	.7470	.8043	-2.739
340.000	.8870	.9495	.8316	.8713	-1.771
400.000	.9164	.9744	.8851	.9142	-0.236
460.000	.9385	.9923	.9228	.9446	0.645

Y1= 0.8000

PRESSURE=1500.0Psia

160.000	.5076	.6956	.1089	.4265	-15.987
220.000	.6982	.8219	.5104	.6519	-6.633
280.000	.7938	.8960	.6902	.7799	-1.755
340.000	.8587	.9418	.7957	.8567	-0.238
400.000	.9010	.9721	.8631	.9065	0.610
460.000	.9279	.9934	.9090	.9411	1.426

Y1= 0.8000

160.000	.4534	.7756	.0092	.5510	21.523
220.000	.6548	.8054	.4178	.6368	-2.751
280.000	.7648	.8853	.6362	.7676	0.368
340.000	.8388	.9372	.7627	.8497	1.295
400.000	.8874	.9718	.8426	.9035	1.819
460.000	.9200	.9960	.8967	.9412	2.303

Y1= 0.8000

PRESSURE=2000.0 Psia.

160.000	.4421	.9601	.0618	.8061	82.336
220.000	.6213	.8134	.3465	.6642	6.910
280.000	.7433	.8825	.5896	.7713	2.720
340.000	.8227	.9365	.7333	.8513	3.478
400.000	.8752	.9740	.8243	.9061	3.535
460.000	.9135	1.0004	.8862	.9450	3.452

Aver. Abs. Deviation. % = 4.9608

COMPRESSIBILITY FACTOR USING THE LENNARD JONES
POTENTIAL FOR CO₂(1)-N-BUTANE(2) MIXTURE

TEMP F	ZMexptl	ZMLJ	ZMLJA 2ndVir	ZMLJA 3rdVir	%DEVIATION ZMLJA
Y1= 0.2000					
PRESSURE= 200.0Psia					
340.000	.9160	.9848	.9213	.9257	1.057
400.000	.9360	.9903	.9401	.9431	0.763
460.000	.9514	.9944	.9537	.9559	0.476
Y1= 0.2000					
PRESSURE= 400.0Psia					
340.000	.8235	.9662	.8250	.8428	2.831
400.000	.8685	.9795	.8711	.8854	1.944
460.000	.8991	.9886	.9025	.9123	1.465
Y1= 0.2000					
PRESSURE= 600.0Psia					
340.000	.7188	.9432	.7005	.7650	6.423
400.000	.7988	.9676	.7909	.8288	3.757
460.000	.8487	.9829	.8460	.8707	2.596
Y1= 0.2000					
PRESSURE= 800.0Psia					
340.000	.6052	.9161	.5318	.6933	14.563
400.000	.7288	.9555	.6973	.7783	6.792
460.000	.7985	.9779	.7839	.8335	4.387
Y1= 0.2000					
PRESSURE=1000.0Psia					
340.000	.4955	.8961	.3094	.6860	38.444
400.000	.6620	.9457	.5904	.7438	12.361
460.000	.7538	.9747	.7178	.8049	6.778

Aver. Abs. Deviation, % = 6.9759

COMPRESSIBILITY FACTOR USING AUGMENTED PENNARD FORMS
POTENTIAL FOR CO₂(1) - CH₄(2) MIXTURE

TEMP F ZM_{exptl} ZM_{LJ} ZM_{LJA} ZM_{LJA} %DEVIATION
2ndvir 3rdvir Z_{LJA}

Y1 = 0.5000

PRESSURE = 200.0 Psia

340.000	.9528	.9894	.9620	.9640	1.111
400.000	.9640	.9936	.9714	.9724	0.913
460.000	.9728	.9968	.9783	.9793	0.669

Y1 = 0.5000

PRESSURE = 400.0 Psia

340.000	.9040	.9778	.9200	.9241	2.741
400.000	.9290	.9870	.9406	.9470	1.937
460.000	.9451	.9936	.9555	.9599	1.570

Y1 = 0.5000

PRESSURE = 600.0 Psia

340.000	.8560	.9653	.8738	.8967	4.756
400.000	.8935	.9802	.9082	.9233	3.338
460.000	.9195	.9908	.9320	.9425	2.490

Y1 = 0.5000

PRESSURE = 800.0 Psia

340.000	.8060	.9522	.8226	.8686	7.766
400.000	.8572	.9737	.8736	.9028	5.319
460.000	.8935	.9884	.9078	.9275	3.900

Y1 = 0.5000

PRESSURE = 1000.0 Psia

340.000	.7580	.9394	.7671	.8484	11.928
400.000	.8245	.9679	.8378	.8871	7.598
460.000	.8700	.9868	.8833	.9157	5.257

Y1 = 0.5000

PRESSURE = 1250.0 Psia

340.000	.7030	.9264	.6941	.8418	19.751
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400.000	.7875	.9628	.7325	.8710	11.370
460.000	.8435	.9864	.8531	.9070	7.522

 $\chi^2 = 0.5000$

PROCESSOR #1500. PSLA

340.000	.6610	.9216	.6252	.8659	30.981
400.000	.7572	.9617	.7492	.8948	15.420
460.000	.8220	.9887	.8246	.9062	10.243

 Aver. Abs. Deviation, % = 7.5004

COMPRESSIBILITY FACTOR USING ARGENTINO TEST AND TOPES

POTENTIAL FOR CO2(1) - ETHANE(2) SYSTEM

TEMP F	ZMexptl	ZMLJ	ZMLJA 2ndvir	ZMLJA 3rdvir	%DEVIATION ZMLJA
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Y1 = 0.7000

PRESSURE = 200.0 Psia

340.000	.9691	.9920	.9724	.9715	0.455
400.000	.9770	.9955	.9798	.9806	0.372
460.000	.9820	.9981	.9854	.9859	0.399

Y1 = 0.7000

PRESSURE = 400.0 Psia

340.000	.9375	.9835	.9430	.9479	1.104
400.000	.9541	.9909	.9589	.9622	0.862
460.000	.9648	.9963	.9704	.9722	0.825

Y1 = 0.7000

PRESSURE = 600.0 Psia

340.000	.9068	.9748	.9119	.9236	1.856
400.000	.9314	.9864	.9373	.9451	1.473
460.000	.9479	.9948	.9553	.9608	1.356

Y1= 0.7000

PRESSURE= 800.0Psia

340.000	.8750	.9660	.8791	.9014	3.020
400.000	.9090	.9822	.9151	.9237	2.279
460.000	.9326	.9937	.9401	.9502	1.985

Y1= 0.7000

PRESSURE=1000.0Psia

340.000	.8458	.9575	.8451	.8825	4.335
400.000	.8885	.9785	.8927	.9166	3.163
460.000	.9171	.9932	.9250	.9413	2.636

Y1= 0.7000

PRESSURE=1250.0Psia

340.000	.8106	.9480	.8015	.8650	6.710
400.000	.8650	.9750	.8648	.9043	4.539
460.000	.9015	.9935	.9068	.9331	3.505

Y1= 0.7000

PRESSURE=1500.0Psia

340.000	.7806	.9413	.7587	.8573	9.823
400.000	.8438	.9734	.8378	.8975	6.867
460.000	.8864	.9952	.8895	.9286	4.763

Aver. Abs. Deviation, % = 2.9390

SYSTEM: CO2(1)-METHANE(2)

TEMP: -65.0000F;

PRESS:IN PSIA

% DEVIATIONS

SLNO.	PRESS	X(1)	Y(1)	AK(1)	VALUES,	Y(1)	AK(1)	VALUES,	Pcalc	DELP	DELK(1)
1	300.000	.9150	.3000	0.3279	.2941	0.3214	319.704	6.568	-1.964		
2	400.000	.8730	.2430	0.2784	.2492	0.2855	402.130	0.533	2.566		
3	573.000	.7280	.1860	0.2555	.2000	0.2747	580.111	1.241	7.507		
4	600.000	.7440	.1950	0.2621	.2035	0.2736	564.885	-5.852	4.384		
5	700.000	.7200	.1850	0.2569	.2075	0.2882	582.570	-16.776	12.154		

Aver. Abs. Deviations, % :

ADEP= 6.1939

ADEK1= 5.7151

SYSTEM: CO2(1)-METHANE(2)

TEMP: -57.0000F; PRESS:IN PSIA

SLNo.	PRESS	X(1)	Y(1)	EXPERIMENTAL VALUES,	AK(1)	Y(1)	CALCULATED VALUES,	AK(1)	Pcalc	% DEVIATIONS Delp	DELK(1)
1	300.000	.9300	.3450	0.3710	0.3611	0.3883	306.650	2.217	4.677		
2	400.000	.8900	.2770	0.3112	.2955	0.3321	395.861	-1.035	6.695		
3	573.000	.7590	.2130	0.2806	.2268	0.2988	587.557	2.540	6.484		
4	600.000	.8470	.2430	0.2869	.2650	0.3129	472.063	-21.323	9.054		
5	700.000	.8320	.3590	0.4315	.2595	0.3119	492.620	-29.626	-27.718		

Aver. Abs. Deviations, % :

ADEP= 11.3481

ADEK1= 10.9255

SYSTEM: CO2(1)-METHANE(2)

TEMP: -25.0000F;

PRESS:IN PSIA

SLNo.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	VALUES,	VALUES,	% DEVIATIONS
							EXPERIMENTAL	CALCULATED	DELK(1)
1	300.000	1.0000	1.0000	1.0000	1.0000	1.0000	195.156	-34.948	0.000
2	400.000	.9370	.5210	0.5560	.5314	0.5672	397.576	-0.606	2.005
3	573.000	.8430	.3600	0.4270	.3795	0.4502	609.844	6.430	5.415
4	600.000	.8690	.3880	0.4465	.4037	0.4645	561.281	-6.453	4.036
5	700.000	.8320	.3590	0.4315	.3724	0.4476	629.732	-10.038	3.743

Aver. Abs. Deviations, % :

ADEP= 11.6951

ADEK1= 3.0399

SYSTEM: CO2(1)-PROPANE(2)

TEMP: -40.0000F; PRESS:IN PSIA

S.No.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)
1	15.000	.0000	.0000	0.0000	.0000	0.0000	.0000	15.803	5.351	0.000	0.000
2	50.000	.1650	.7100	4.3000	.6950	4.2123	.6950	49.865	-0.270	-2.040	-2.040
3	100.000	.5280	.8820	1.6700	.8829	1.6722	.8829	102.769	2.769	0.129	0.129
4	145.000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	146.355	0.935	0.000	0.000

Aver. Abs. Deviations, % :

ADEP= 2.3310

ADEK1= 0.5423

SYSTEM: CO2(1)-PROPANE(2)

TEMP: -4.0000F; PRFS:TN PSIA

EXPERIMENTAL VALUES, CALCULATED VALUES, % DEVIATIONS

SUNO.	PRFS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELP	DFLK(1)
1	34.000	.0000	.0000	0.0000	.0000	0.0000	34.960	2.823	0.000
2	100.000	.1900	.6560	3.4500	.6762	3.5590	98.460	-1.540	3.161
3	200.000	.5180	.8510	1.6400	.8613	1.6627	185.088	-7.456	1.385
4	250.000	.8200	.9280	1.1300	.9357	1.1411	249.213	-0.315	0.986
5	285.000	1.0000	1.0000	1.0000	1.0000	1.0000	285.117	0.041	0.000

Aver. Abs. Deviations, % :

ADEP= 2.4349

ADEK1= 1.1063

SYSTEM: CO2(1)-PROPANE(2)

TEMP: 11.8000F; PRESS:1N PSIA

SLNo.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)
1	35.280	.0000	.0000	0.0000	.0000	0.0000	.0000	47.690	35.176	0.000	0.000
2	48.510	.0300	.3130	10.4330	.2235	7.4498	.2235	61.177	26.112	-28.594	-28.594
3	66.150	.0550	.5130	9.3270	.3442	6.2573	.3442	72.044	8.910	-32.912	-32.912
4	91.140	.1250	.6610	5.2880	.5438	4.3502	.5438	100.509	10.280	-17.735	-17.735
5	113.190	.1770	.7230	4.0850	.6278	3.5468	.6278	120.573	6.523	-13.174	-13.174
6	141.120	.2460	.7760	3.1540	.7021	2.8541	.7021	145.593	3.170	-9.510	-9.510
7	163.170	.3220	.8110	2.5190	.7571	2.3514	.7571	171.799	5.288	-6.655	-6.655
8	188.160	.4010	.8450	2.1070	.7982	1.9905	.7982	197.559	4.995	-5.531	-5.531
9	214.620	.5440	.8780	1.6140	.8514	1.5651	.8514	241.525	12.536	-3.033	-3.033
10	241.080	.6940	.9060	1.3050	.8939	1.2880	.8939	285.145	18.278	-1.305	-1.305
11	266.070	.8680	.9510	1.0960	.9432	1.0866	.9432	335.197	25.981	-0.857	-0.857
12	283.710	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	370.574	30.617	0.000	0.000

Aver. Abs. Deviations, % :

ADEP= 15.6554

ADEK1= 9.9421

SYSTEM: CO2(1)-PROPANE(2)

TEMP: 32.0000F; PRESS:IN PSIA

EXPERIMENTAL VALUES, CALCULATED VALUES, % DEVIATIONS

SLNo.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELP	DELK(1)
1	67.000	.0000	.0000	0.0000	.0000	0.0000	69.018	3.013	0.000
2	100.000	.0550	.3300	6.0000	.3127	5.6852	97.483	-2.517	-5.247
3	200.000	.2600	.6830	2.6300	.6872	2.6429	194.384	-2.808	0.490
4	300.000	.4800	.8180	1.7000	.8131	1.6940	285.964	-4.679	-0.352
5	400.000	.7120	.8820	1.2400	.8889	1.2484	381.175	-4.706	0.680
6	507.000	1.0000	1.0000	1.0000	1.0000	1.0000	504.869	-0.420	0.000

Aver.Abs.Deviations,% :

ADEP= 3.0238

ADEK1= 1.1282

SYSTEM: CO2(1)-PROPANE(2)

TEMP: 32.0000F; PRESS:IN PSIA

EXPERIMENTAL VALUES, CALCULATED VALUES, % DEVIATIONS

SLNO.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELK(1)
1	69.090	.0000	.0000	0.0000	.0000	0.0000	69.018	-0.104
2	80.850	.0130	.1270	10.0450	.0967	7.4375	75.937	-6.076
3	107.310	.0340	.3300	9.6660	.2187	6.4329	87.093	-18.840
4	149.940	.0860	.5230	6.1460	.4149	4.8249	113.773	-24.121
5	216.090	.1760	.6740	3.8290	.5944	3.3770	156.621	-27.521
6	277.830	.2910	.7450	2.5630	.7116	2.4455	207.657	-25.258
7	358.680	.4610	.8280	1.7960	.8050	1.7462	278.691	-22.301
8	402.780	.6220	.8590	1.3820	.8614	1.3849	343.864	-14.627
9	438.060	.7190	.8930	1.2420	.8907	1.2388	383.883	-12.367
10	470.400	.8400	.9290	1.1050	.9288	1.1057	436.233	-7.263
11	498.330	.9530	.9760	1.0250	.9744	1.0225	485.613	-2.552
12	505.680	1.0000	1.0000	1.0000	1.0000	1.0000	504.869	-0.160

Aver. Abs. Deviations, % :

ADEP= 13.4325

ADEK1= 8.4033

SYSTEM: CO2(1)-PROPANE(2)

TEMP: 40.0000F; PRESS:IN PSIA

SLNo.	PRESS	X(1)	Y(1)	AK(1)	VALUES,	Y(1)	AK(1)	VALUES,	Pcalc	% DEVIATIONS	DELK(1)
			EXPERIMENTAL		VALUES,		CALCULATED				
1	79.000	.0000	.0000	0.0000	.0000	.0000	0.0000	78.731	-0.340	0.000	0.000
2	100.000	.0247	.2056	8.3200	.1607	.1607	6.5049	93.061	-6.939	-21.816	
3	150.000	.0884	.4676	5.2900	.4071	.4071	4.6051	128.385	-14.410	-12.948	
4	200.000	.1602	.6036	3.7700	.5562	.5562	3.4722	165.334	-17.333	-7.900	
5	250.000	.2402	.6864	2.8580	.6551	.6551	2.7273	204.517	-18.193	-4.575	
6	300.000	.3316	.7431	2.2410	.7277	.7277	2.1944	247.064	-17.645	-2.080	
7	350.000	.4361	.7876	1.8060	.7841	.7841	1.7979	294.523	-15.850	-0.446	
8	400.000	.5532	.8309	1.5020	.8307	.8307	1.5017	347.175	-13.206	-0.020	
9	450.000	.6714	.8688	1.2940	.8697	.8697	1.2953	402.059	-10.654	0.099	
10	500.000	.7956	.9102	1.1440	.9095	.9095	1.1432	462.985	-7.403	-0.070	
11	550.000	.9401	.9702	1.0320	.9669	.9669	1.0285	537.313	-2.307	-0.338	
12	566.500	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	566.326	-0.031	0.000	

Aver,Abs.Deviations,% :

ADFP= 10.3593

ADEK1= 4.1910

SYSTEM: C02(1)-PROPANE(2)

TEMP: 70.0000F; PRESS:IN PSIA

SLNO.	PRESS	X(1)	Y(1)	AK(1)	VALUES,	Y(1)	AK(1)	VALUES,	Y(1)	AK(1)	Pcalc	% DEVIATIONS	Delp	DELK(1)
1	125.000	.0000	.0000	0.0000	0.0000	.0000	0.0000	125.862	0.690	0.000	0.690	0.000	0.000	0.000
2	150.000	.0245	.1618	6.6000	6.6000	.1312	5.3538	143.574	-4.284	5.3538	-4.284	-18.882	-18.882	-18.882
3	200.000	.0742	.3589	4.8400	4.8400	.3137	4.2284	178.443	-10.778	4.2284	-10.778	-12.636	-12.636	-12.636
4	250.000	.1274	.4812	3.7800	3.7800	.4402	3.4556	213.797	-14.481	3.4556	-14.481	-8.583	-8.583	-8.583
5	300.000	.1834	.5634	3.0700	3.0700	.5319	2.9000	249.459	-16.847	2.9000	-16.847	-5.536	-5.536	-5.536
6	350.000	.2423	.6235	2.5730	2.5730	.6014	2.4820	286.329	-18.192	2.4820	-18.192	-3.535	-3.535	-3.535
7	400.000	.3048	.6718	2.2040	2.2040	.6567	2.1547	323.412	-19.147	2.1547	-19.147	-2.238	-2.238	-2.238
8	450.000	.3727	.7148	1.9180	1.9180	.7033	1.8870	363.798	-19.156	1.8870	-19.156	-1.614	-1.614	-1.614
9	500.000	.4443	.7518	1.6920	1.6920	.7419	1.6698	407.267	-18.547	1.6698	-18.547	-1.313	-1.313	-1.313
10	550.000	.5178	.7814	1.5090	1.5090	.7761	1.4989	452.361	-17.753	1.4989	-17.753	-0.673	-0.673	-0.673
11	600.000	.5937	.8092	1.3630	1.3630	.8062	1.3579	502.764	-16.206	1.3579	-16.206	-0.374	-0.374	-0.374
12	650.000	.6722	.8368	1.2450	1.2450	.8356	1.2430	558.849	-14.023	1.2430	-14.023	-0.159	-0.159	-0.159
13	700.000	.7516	.8673	1.1550	1.1550	.7516	1.0000	350.317	-49.955	1.0000	-49.955	-13.421	-13.421	-13.421
14	750.000	.8275	.9011	1.0890	1.0890	.8275	1.0000	379.657	-49.379	1.0000	-49.379	-8.173	-8.173	-8.173
15	800.000	.9046	.9417	1.0410	1.0410	.9045	0.9999	411.906	-48.512	0.9999	-48.512	-3.950	-3.950	-3.950
16	850.000	.9805	.9874	1.0070	1.0070	.9805	1.0000	449.573	-47.109	1.0000	-47.109	-0.697	-0.697	-0.697
17	860.900	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	462.397	-46.289	1.0000	-46.289	0.000	0.000	0.000

Aver. Abs. Deviations, % :

ADEP= 24.1969

ADEK1= 4.8109

SYSTEM: CO2(1)-PROPANE(2)

TEMP: 100.0000F; PRESS:IN PSIA

EXPERIMENTAL VALUES, CALCULATED VALUES, % DEVIATIONS

SLNO.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELP	DELK(1)
1	188.700	.0000	.0000	0.0000	.0000	0.0000	189.847	0.608	0.000
2	200.000	.0081	.0472	5.8300	.0382	4.7166	197.530	-1.235	-19.098
3	250.000	.0495	.2281	4.6100	.1951	3.9421	232.017	-7.193	-14.487
4	300.000	.0926	.3511	3.7900	.3114	3.3628	267.562	-10.813	-11.271
5	350.000	.1361	.4370	3.2100	.3989	2.9310	300.731	-14.077	-8.690
6	400.000	.1799	.4994	2.7760	.4667	2.5943	333.979	-16.505	-6.546
7	450.000	.2248	.5481	2.4390	.5222	2.3229	366.584	-18.537	-4.758
8	500.000	.2709	.5876	2.1690	.5685	2.0987	399.293	-20.141	-3.242
9	550.000	.3191	.6213	1.9470	.6083	1.9062	433.421	-21.196	-2.093
10	600.000	.3693	.6514	1.7640	.6429	1.7410	468.961	-21.840	-1.304
11	650.000	.4212	.6781	1.6100	.6734	1.5987	506.296	-22.108	-0.702
12	700.000	.4735	.7013	1.4810	.6995	1.4772	545.215	-22.112	-0.255
13	750.000	.5272	.7238	1.3730	.5268	0.9992	356.918	-52.411	-27.228
14	800.000	.5814	.7448	1.2810	.5814	1.0000	376.982	-52.877	-21.938
15	850.000	.6346	.7647	1.2050	.6346	1.0000	394.335	-53.608	-17.014
16	900.000	.6861	.7801	1.1370	.6861	1.0000	413.543	-54.051	-12.051
17	950.000	.7363	.7908	1.0740	.7363	1.0000	431.102	-54.621	-6.891
18	1000.000	.7902	.7973	1.0090	.7902	1.0000	453.052	-54.695	-0.893
19	1002.500	.7950	.7950	1.0000	.7948	0.9997	454.117	-54.702	-0.027

Aver. Abs. Deviations, % :

SYSTFM: CO2(1)-PROPANE(2)

TEMP: 130.0000F; PRESS:IN PSIA

% DEVIATIONS

VALUES,

CALCULATED

VALUES,

EXPERIMENTAL

Y(1)

AK(1)

Y(1)

AK(1)

Pcalc

DELK(1)

DELK(1)

DELK(1)

DELK(1)

DELK(1)

DELK(1)

DELK(1)

DELK(1)

SINO.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELK(1)
1	237.500	.0000	.0000	0.0000	.0000	0.0000	275.351	15.937
2	300.000	.0176	.0734	4.1700	.0636	3.6157	292.608	-2.464
3	350.000	.0526	.1873	3.5600	.1679	3.1918	325.481	-7.005
4	400.000	.0882	.2739	3.1000	.2519	2.8563	356.516	-10.871
5	450.000	.1246	.3425	2.7490	.3206	2.5731	388.118	-13.752
6	500.000	.1618	.3980	2.4600	.3784	2.3390	418.423	-16.315
7	550.000	.1992	.4476	2.2220	.4265	2.1412	448.546	-18.446
8	600.000	.2376	.4804	2.0220	.4680	1.9698	478.224	-20.296
9	650.000	.2770	.5024	1.8500	.5033	1.8170	508.063	-21.836
10	700.000	.3171	.5394	1.7010	.3168	0.9990	416.921	-40.440
11	750.000	.3577	.5619	1.5710	.3577	0.9999	388.423	-48.210
12	800.000	.3996	.5806	1.4530	.3996	1.0000	401.450	-49.819
13	850.000	.4403	.5896	1.3390	.4403	1.0000	414.519	-51.233
14	900.000	.4840	.5968	1.2330	.4840	1.0000	428.303	-52.411
15	950.000	.4306	.5980	1.1270	.4306	1.0000	411.316	-56.704
16	992.000	.4880	.5880	1.0000	.4880	1.0000	428.954	-56.759

Aver. Abs. Deviations, % :

ADEP= 30.1561

ADEK1= 13.4438

TEMP: 32.0000F; PRESS:IN PSIA

EXPERIMENTAL VALUES, CALCULATED VALUES, % DEVIATIONS

SINo.	PRESS	X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELP	DELK(1)
1	35.280	.0300	.5880	19.6000	.5292	17.6389	31.256	-11.407	-10.006
2	57.330	.0570	.7410	13.0000	.6715	11.7816	45.950	-19.850	-9.373
3	85.260	.0940	.8260	8.7872	.7616	8.1020	65.499	-23.177	-7.797
4	122.010	.1440	.8770	6.0903	.8234	5.7178	90.226	-26.050	-6.117
5	155.820	.2000	.9000	4.5000	.8604	4.3021	115.905	-25.616	-4.397
6	189.630	.2750	.9160	3.3309	.8902	3.2369	149.531	-21.146	-2.822
7	224.910	.3340	.9200	2.7545	.9042	2.7071	174.634	-22.354	-1.719
8	261.660	.3980	.9320	2.3417	.9155	2.3002	201.257	-23.085	-1.773
9	294.000	.4690	.9420	2.0085	.9250	1.9723	231.148	-21.378	-1.803
10	336.630	.5680	.9510	1.6743	.9365	1.6488	273.248	-18.828	-1.523
11	377.790	.6810	.9630	1.4141	.9481	1.3923	324.058	-14.223	-1.542
12	420.420	.8040	.9740	1.2145	.9614	1.1958	386.833	-7.989	-1.538
13	463.050	.9110	.9830	1.0790	.9778	1.0733	448.125	-3.223	-0.527

Aver. Abs. Deviations, % :

ADEP= 18.3328

ADEK1= 3.9182

SYSTEM: C02(1)-N-BUTANE(2)

TEMP: 69.7800F; PRESS:IN PSIA

SLNO.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)
1	59.976	.0066	.1320	20.0000	.1409	21.3525	36.200	-39.643	6.763	6.763	
2	79.968	.0220	.3320	15.0909	.3532	16.0562	47.756	-40.281	6.397	6.397	
3	100.107	.0360	.4540	12.6111	.4722	13.1178	57.856	-42.206	4.017	4.017	
4	125.097	.0560	.5560	9.9286	.5816	10.3856	72.109	-42.357	4.603	4.603	
5	150.087	.0760	.6280	8.2632	.6520	8.5793	86.588	-42.308	3.826	3.826	
6	175.077	.0950	.6790	7.1474	.6999	7.3675	99.632	-43.092	3.080	3.080	
7	200.067	.1151	.7140	6.2033	.7379	6.4109	113.189	-43.424	3.347	3.347	
8	238.434	.1550	.7650	4.9355	.7906	5.1010	138.672	-41.840	3.353	3.353	
9	300.027	.1950	.7980	4.0923	.8255	4.2336	163.149	-45.622	3.452	3.452	
10	350.154	.2390	.8220	3.4393	.8522	3.5658	189.202	-45.966	3.678	3.678	
11	408.954	.2840	.8400	2.9577	.8727	3.0730	214.076	-47.653	3.898	3.898	
12	450.114	.3300	.8550	2.5909	.8880	2.6908	239.925	-46.697	3.856	3.856	
13	500.094	.3780	.8670	2.2937	.9003	2.3818	266.698	-46.670	3.844	3.844	
14	600.201	.4780	.8860	1.8536	.9197	1.9240	321.702	-46.401	3.803	3.803	
15	700.161	.5840	.9000	1.5411	.9339	1.5992	384.865	-45.032	3.770	3.770	
16	800.268	.6980	.9100	1.3037	.9462	1.3556	462.694	-42.183	3.980	3.980	
17	900.228	.7860	.9250	1.1768	.7854	0.9993	86.323	-90.411	-15.090	-15.090	
18	1000.335	.8710	.9440	1.0838	.8707	0.9996	89.698	-91.033	-7.769	-7.769	
19	1005.627	.0980	.9490	9.6837	.7062	7.2059	101.742	-89.883	-25.587	-25.587	6
20	1057.224	.9400	.9400	1.0000	.9398	0.9998	87.615	-91.713	-0.016	-0.016	6

Aver. Abs. Deviations, % :

ADEP= 53.2208

SYSTEM: CO2(1)-N-BUTANE(2)

TEMP: 100.0000F; PRESS:IN PSIA

SLNo.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)
1	51.500	.0000	.0000	0.0000	.0000	0.0000	.0000	53.460	3.807	0.000	0.000
2	100.000	.0340	.4540	12.4900	.3801	11.1785	.3801	83.112	-16.888	-10.500	-10.500
3	200.000	.1150	.7140	6.2100	.6712	5.8369	.6712	150.940	-24.530	-6.009	-6.009
4	300.000	.1960	.7980	4.0700	.7729	3.9431	.7729	211.872	-29.376	-3.117	-3.117
5	400.000	.2840	.8400	2.9600	.8298	2.9219	.8298	272.237	-31.941	-1.286	-1.286
6	500.000	.3780	.8670	2.2940	.8647	2.2876	.8647	333.750	-33.250	-0.280	-0.280
7	600.000	.4780	.8860	1.8520	.8883	1.8584	.8883	400.910	-33.182	0.347	0.347
8	700.000	.5840	.9000	1.5400	.9060	1.5514	.9060	479.284	-31.531	0.740	0.740
9	800.000	.6890	.9100	1.3210	.6890	1.0000	.6890	294.917	-63.135	-24.302	-24.302
10	900.000	.7860	.9250	1.1770	.7860	1.0000	.7860	356.461	-60.393	-15.040	-15.040
11	1000.000	.8710	.9440	1.0840	.8707	0.9997	.8707	419.860	-58.014	-7.778	-7.778
12	1095.000	.9400	.9400	1.0000	.9400	1.0000	.9400	487.792	-55.453	-0.000	-0.000

Aver,Abs.Deviations,% :

ADEP= 36.7916

ADEK1= 5.7832

SYSTEM: C02(1)-ISOBUTANE(2)

TEMP: 32.0000F; PRESS:IN PSIA

S.No.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)	DELK(1)
1	22.785	.0000	.0000	0.0000	.0000	0.0000	21.962	-3.613	0.000		
2	39.600	.0220	.4220	19.1820	.3567	16.2135	35.581	-10.354	-15.475		
3	51.450	.0370	.5410	14.6220	.4810	13.0011	44.127	-14.233	-11.085		
4	61.740	.0380	.6230	16.3950	.4868	12.8116	44.867	-27.329	-21.856		
5	74.970	.0530	.6900	13.0100	.5684	10.7249	53.221	-29.010	-17.621		
6	91.140	.0730	.7440	10.1920	.6423	8.7990	64.449	-29.286	-13.667		
7	108.780	.0980	.7830	7.9900	.7040	7.1836	78.293	-28.027	-10.092		
8	123.480	.1400	.8000	5.3600	.7788	5.2270	105.558	-14.514	-2.645		
9	144.060	.1660	.8300	5.0000	.7956	4.7928	114.302	-20.657	-4.145		
10	171.990	.2240	.8630	3.8530	.8354	3.7293	143.927	-16.317	-3.211		
11	214.620	.3170	.9770	2.7670	.8725	2.7524	187.935	-12.434	-0.529		
12	242.550	.3780	.8990	2.3780	.8869	2.3462	216.351	-10.801	-1.336		
13	255.780	.4030	.9130	2.2660	.8920	2.2133	227.335	-11.121	-2.324		
14	266.070	.4160	.9140	2.1970	.8947	2.1506	232.729	-12.531	-2.110		
15	310.170	.5130	.9220	1.7970	.9081	1.7702	276.268	-10.930	-1.491		

Aver. Abs. Deviations, % :

ADFP# 16.7438

ADFK1= 7.1726

SYSTEM: CO2(1)-N-PENTANE(2)

TEMP: 40,1000F; PRESS:IN PSIA

SLNo.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DELK(1)	DELK(1)	DELK(1)
1	4,300	.0000	.0000	0.0000	.0000	0.0000	.0000	4.247	-1.225	0.000	0.000
2	33,000	.0290	.8528	29.4070	.7510	25.8955	.7510	21.364	-35.262	-11.941	-11.941
3	82,000	.0856	.9449	11.0390	.8790	10.2682	.8790	51.757	-36.881	-6.983	-6.983
4	160,000	.1834	.9709	5.2940	.9236	5.0362	.9236	100.632	-37.105	-4.869	-4.869
5	247,000	.3179	.9803	3.0840	.9422	2.9638	.9422	161.850	-34.474	-3.897	-3.897
6	325,000	.4858	.9846	2.0270	.9490	1.9535	.9490	238.416	-26.641	-3.627	-3.627
7	397,000	.6255	.9872	1.5780	.9494	1.5179	.9494	306.717	-22.741	-3.808	-3.808
8	471,000	.8229	.9874	1.2020	.9593	1.1657	.9593	438.180	-6.968	-3.016	-3.016

Aver. Abs. Deviations, % :

ADEP= 25.1622

ADEK1= 4.7676

SYSTEM: CO2(1)-N-HEXANE(2)

TEMP: 112.0000F; PRESS:IN PSIA

SLNo.	PRESS	EXPERIMENTAL		VALUES,		CALCULATED		VALUES,		% DEVIATIONS	
		X(1)	Y(1)	AK(1)	Y(1)	AK(1)	Y(1)	Pcalc	DEL	DELK(1)	
1	113.000	.0800	.9490	11.8625	.9251	11.5635	84.978	-24.798	-2.521		
2	240.000	.1700	.9720	5.7176	.9566	5.6271	158.897	-33.793	-1.583		
3	354.000	.2520	.9770	3.8770	.9762	3.8740	269.691	-23.816	-0.078		
4	480.000	.3560	.9820	2.7584	.9767	2.7435	334.731	-30.264	-0.542		
5	600.000	.4500	.9820	2.1822	.9871	2.1935	449.646	-25.059	0.518		
6	733.000	.5740	.9840	1.7143	.9999	1.7421	5.731	-99.218	1.621		
7	844.000	.6870	.9850	1.4338	.9919	1.4438	690.547	-18.182	0.701		
8	973.000	.8290	.9840	1.1870	.8286	0.9995	268.977	-72.356	-15.794		
9	1039.000	.8820	.9820	1.1134	.8817	0.9997	349.777	-66.335	-10.209		
10	1085.000	.9150	.9810	1.0721	.9147	0.9997	406.176	-62.564	-6.757		

Aver.Abs.Deviations,% :

ADEP= 45.6386

ADEK1= 4.0324

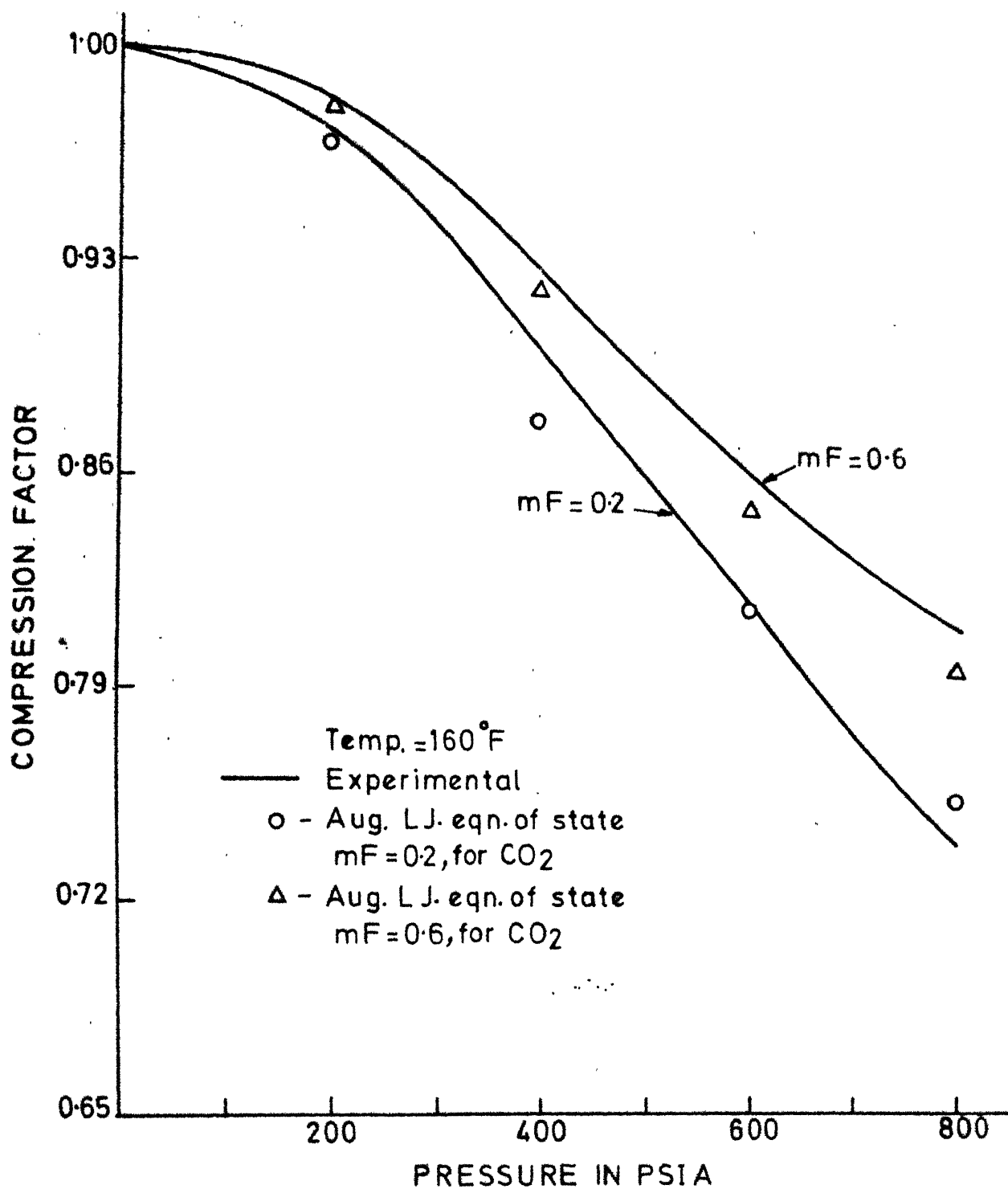


FIG. 1 COMPRESSION FACTOR OF CARBONDIOXIDE - ETHANE-MIXTURE

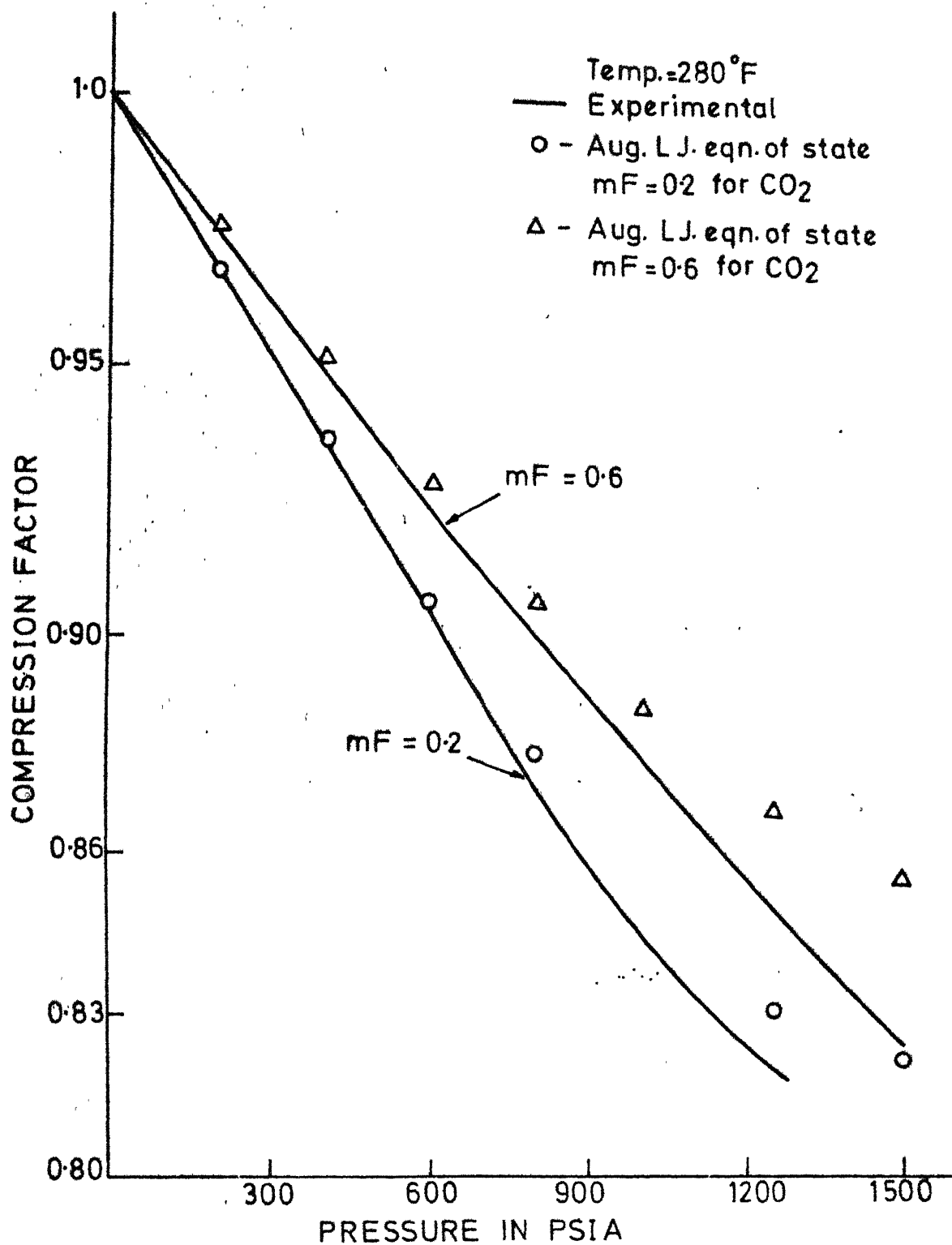


FIG. 2 COMPRESSION FACTOR OF CARBONDIOXIDE
ETHANE-MIXTURE

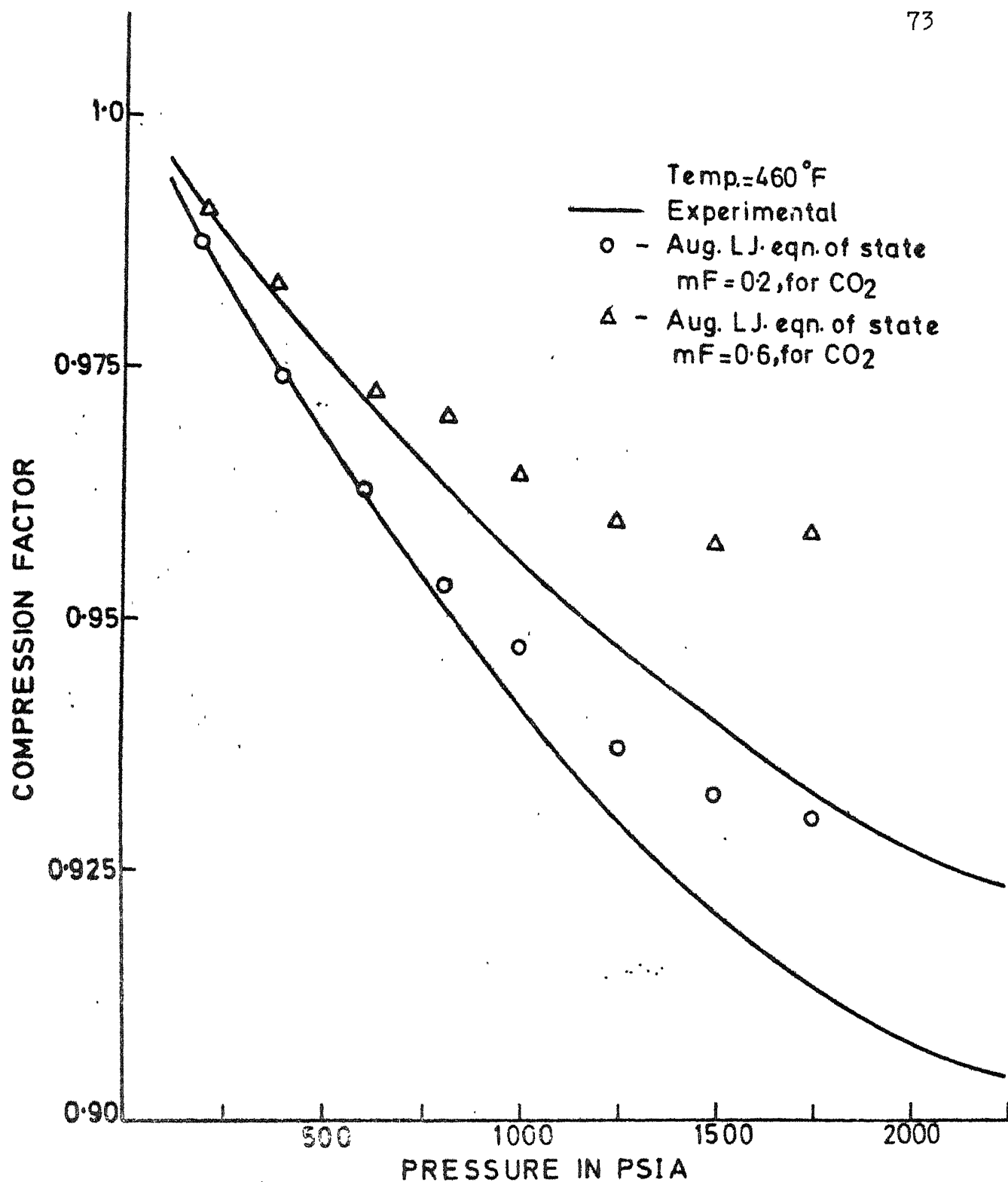


FIG. 3 COMPRESSION FACTOR OF CARBONDIOXIDE-ETHANE MIXTURE

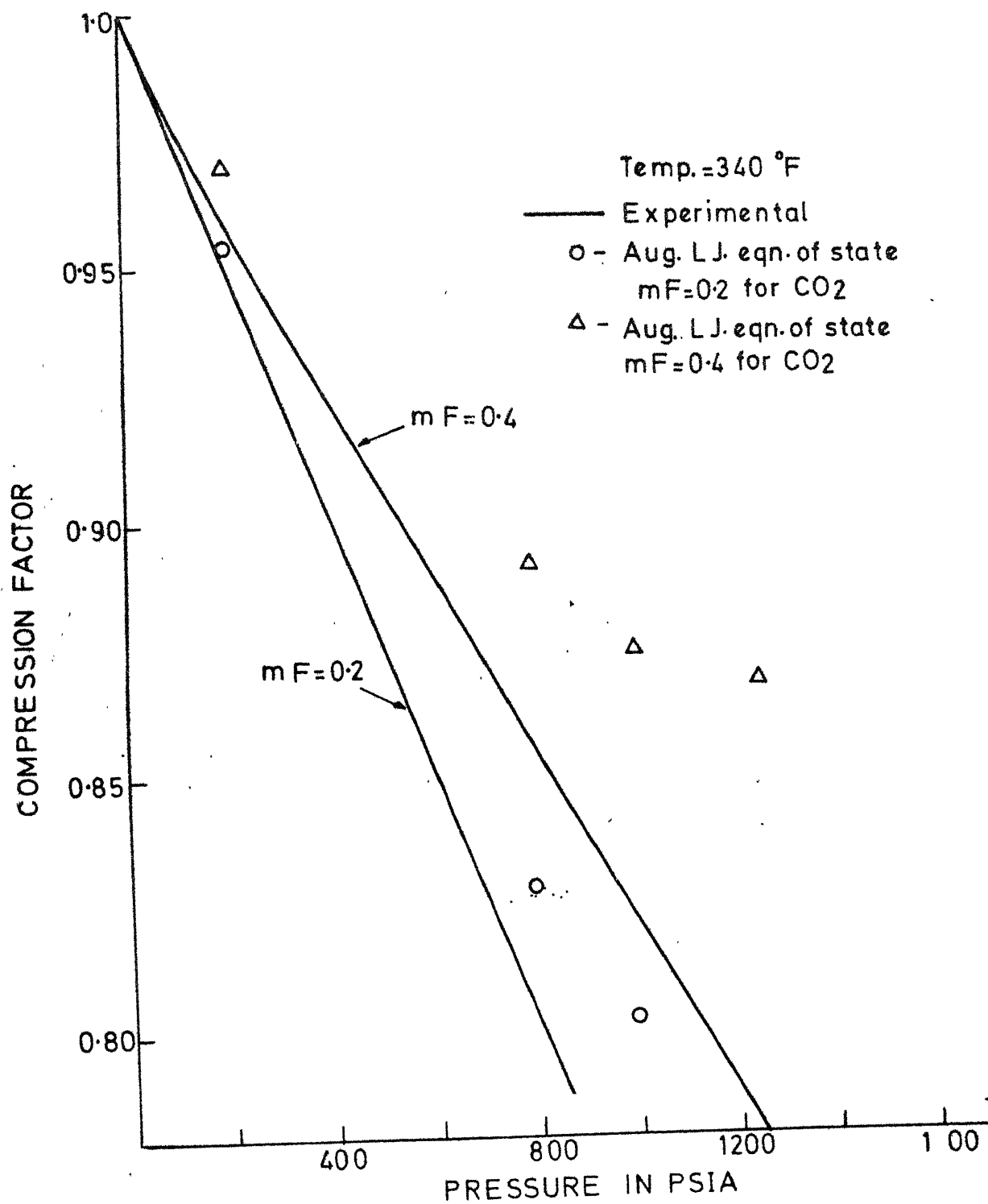


FIG. 4 COMPRESSION FACTOR OF CARBONDIOXIDE
PROPANE MIXTURES

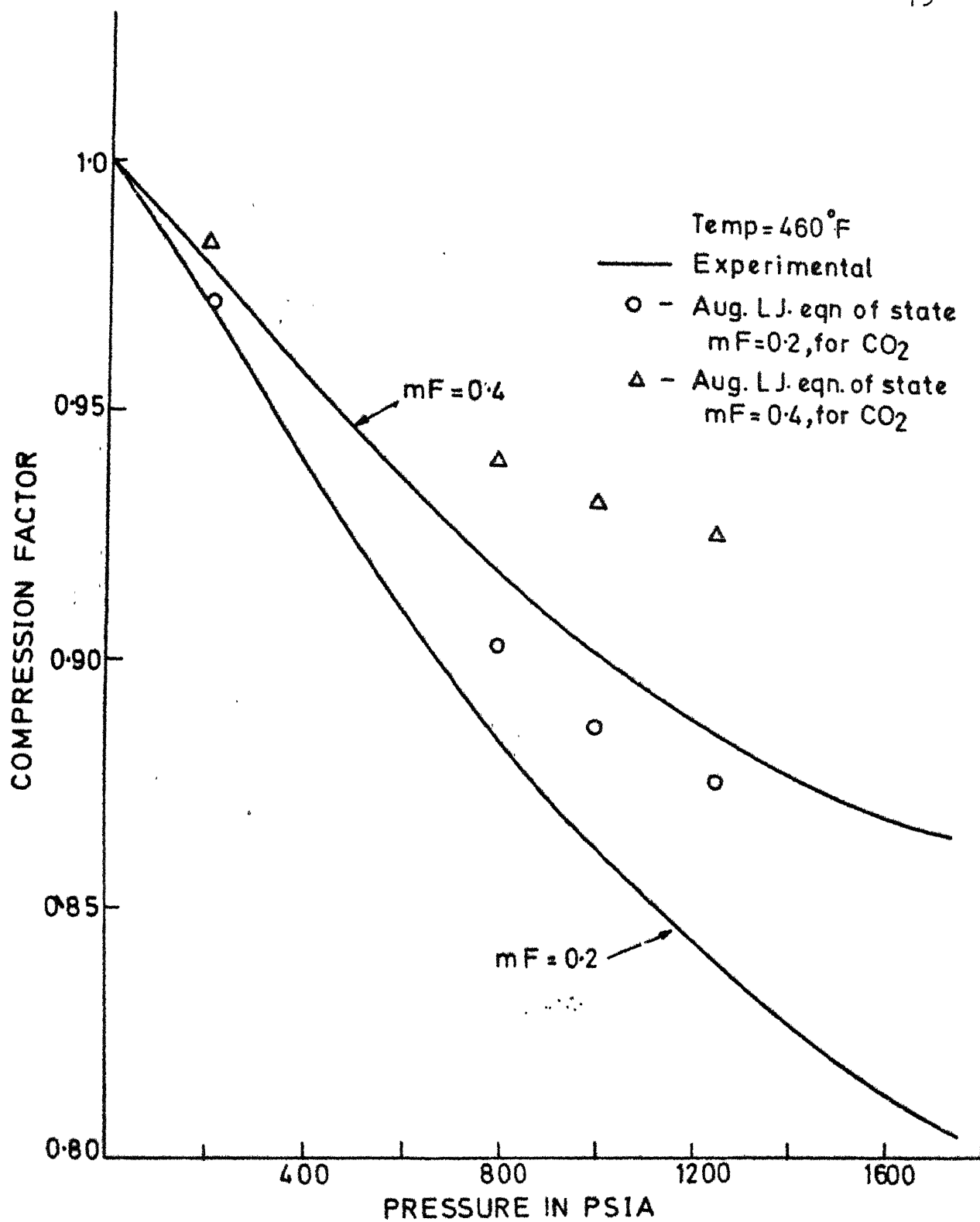


FIG. 5 COMPRESSION FACTOR OF CARBONDIOXIDE-PROPANE MIXTURES

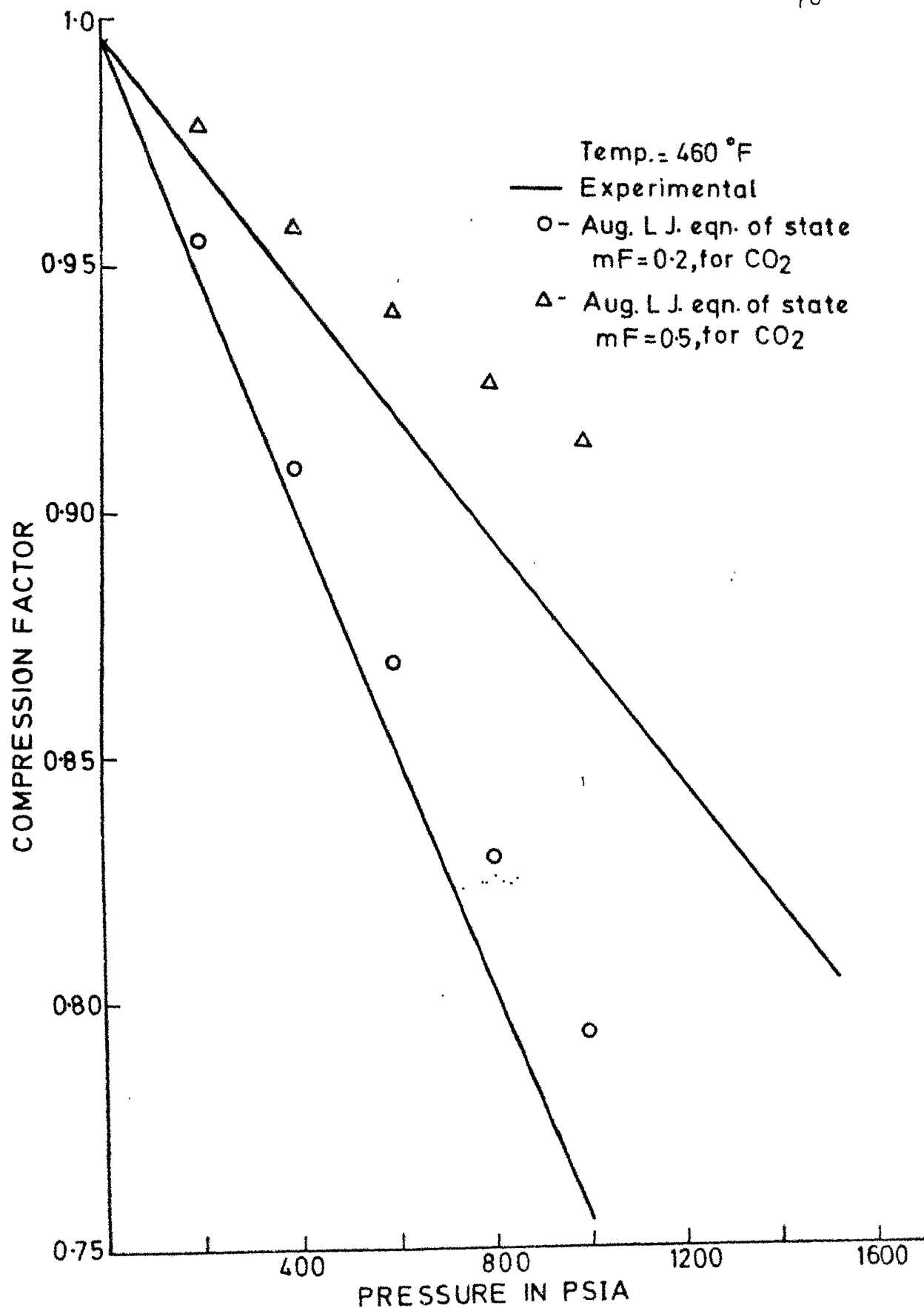


FIG. 6 COMPRESSION FACTOR OF CARBONDIOXIDE n BUTANE MIXTURE

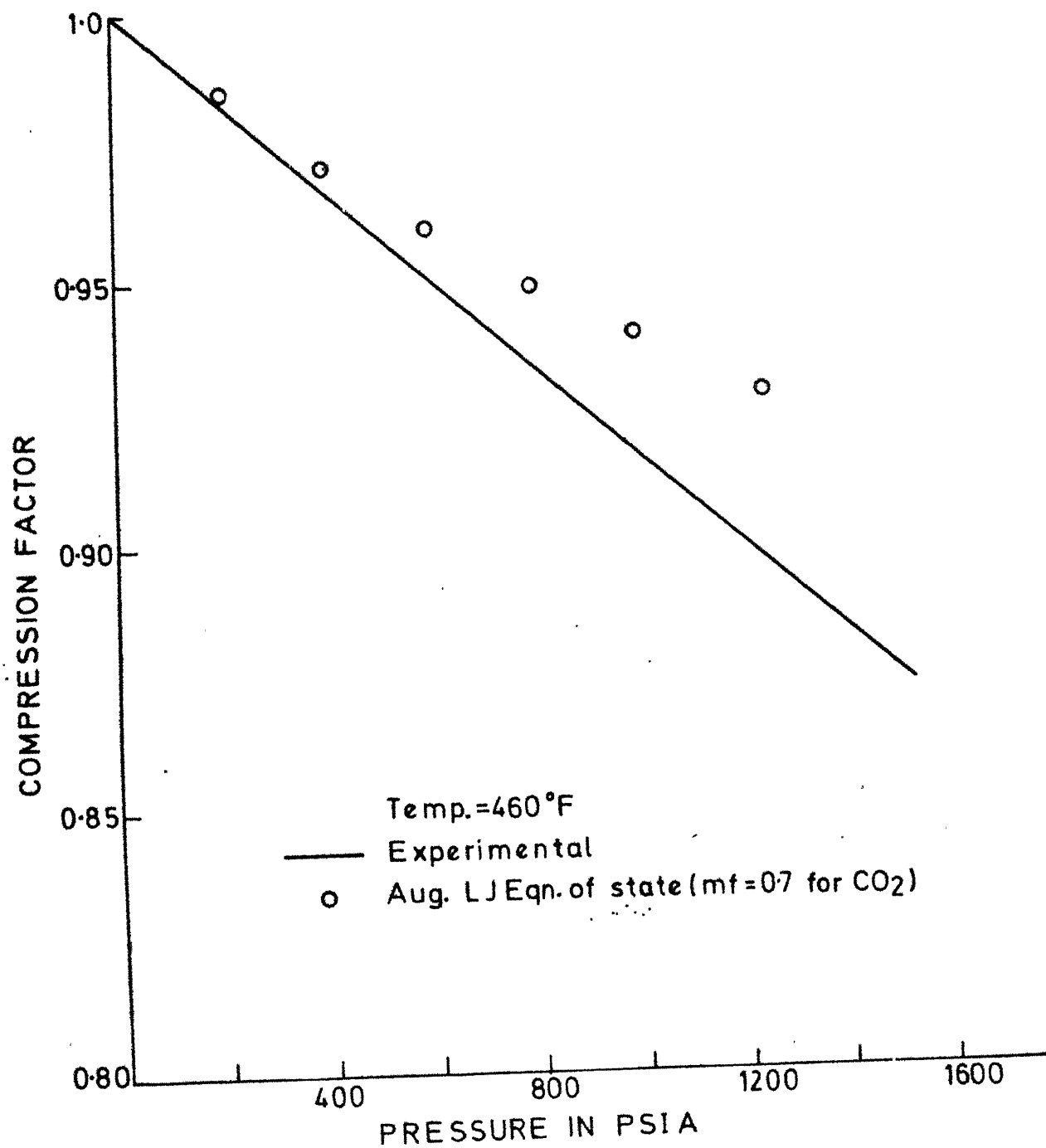


FIG. 7 COMPRESSION FACTOR OF CARBONDIOXIDE-
n-BUTANE MIXTURE

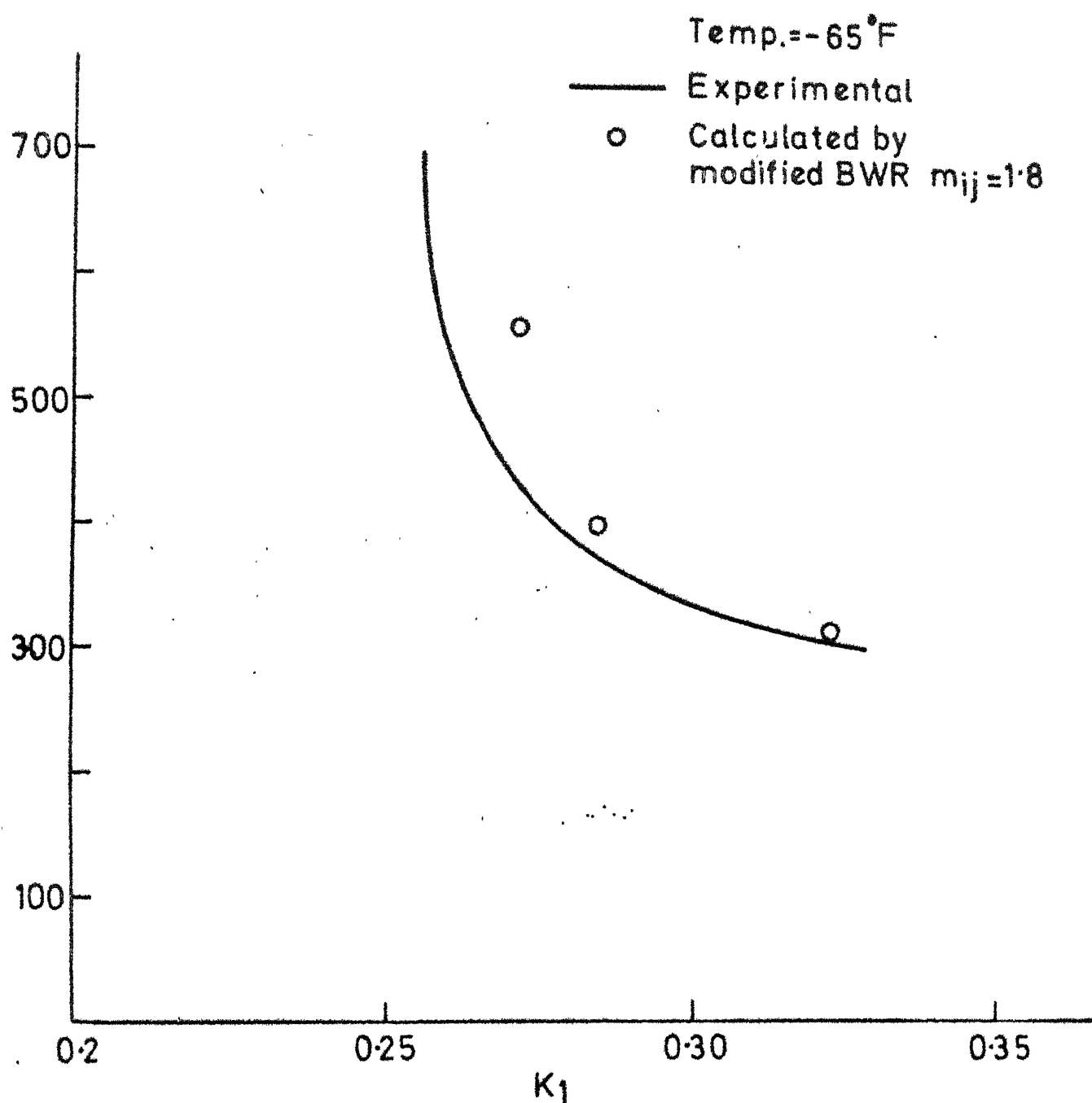


FIG. 8 EQUILIBRIUM VAPORIZATION RATIO $K=y/x$ FOR CO_2 METHANE

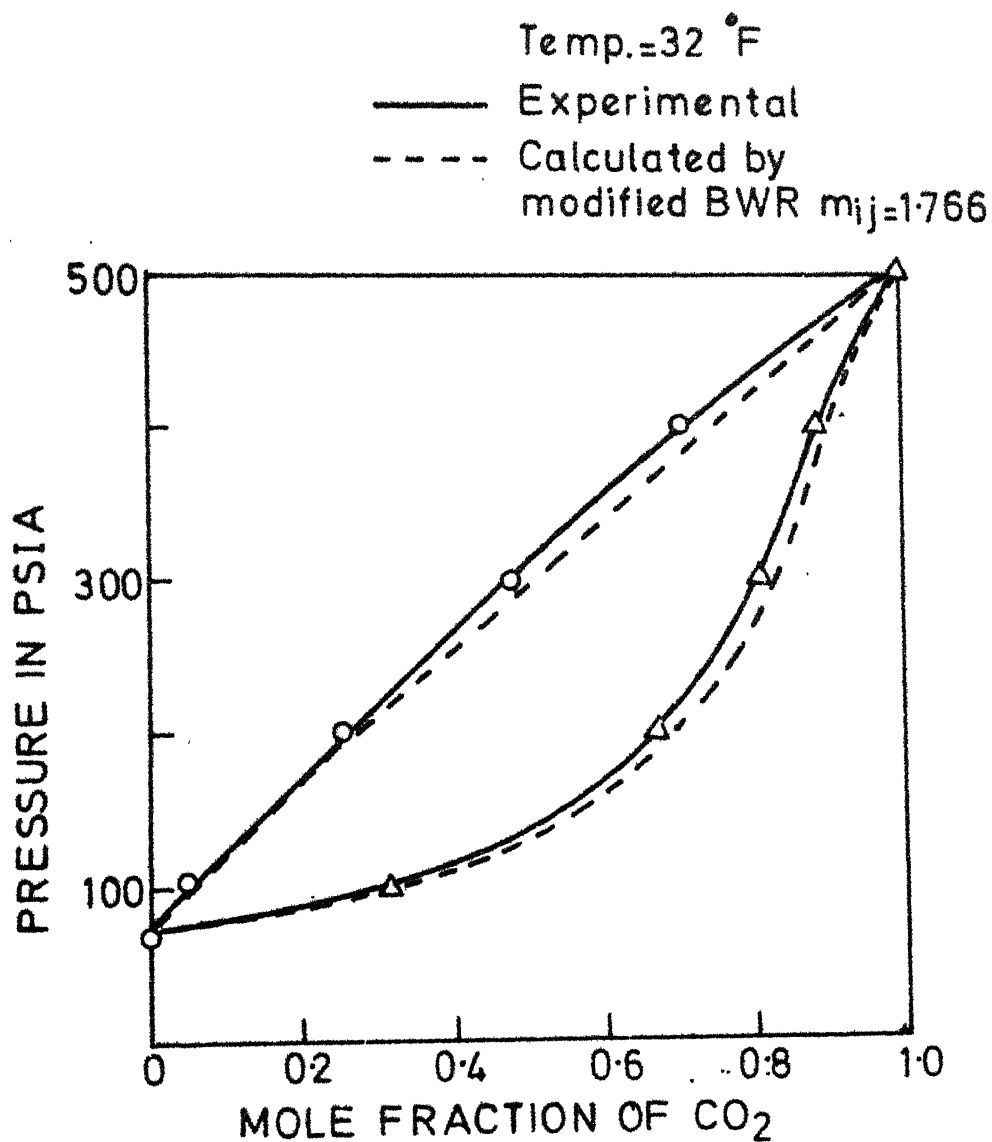


FIG. 9 EQUILIBRIUM VAPORIZATION RATIO $K=y/x$
FOR CARBONDIOXIDE-PROPANE MIXTURE

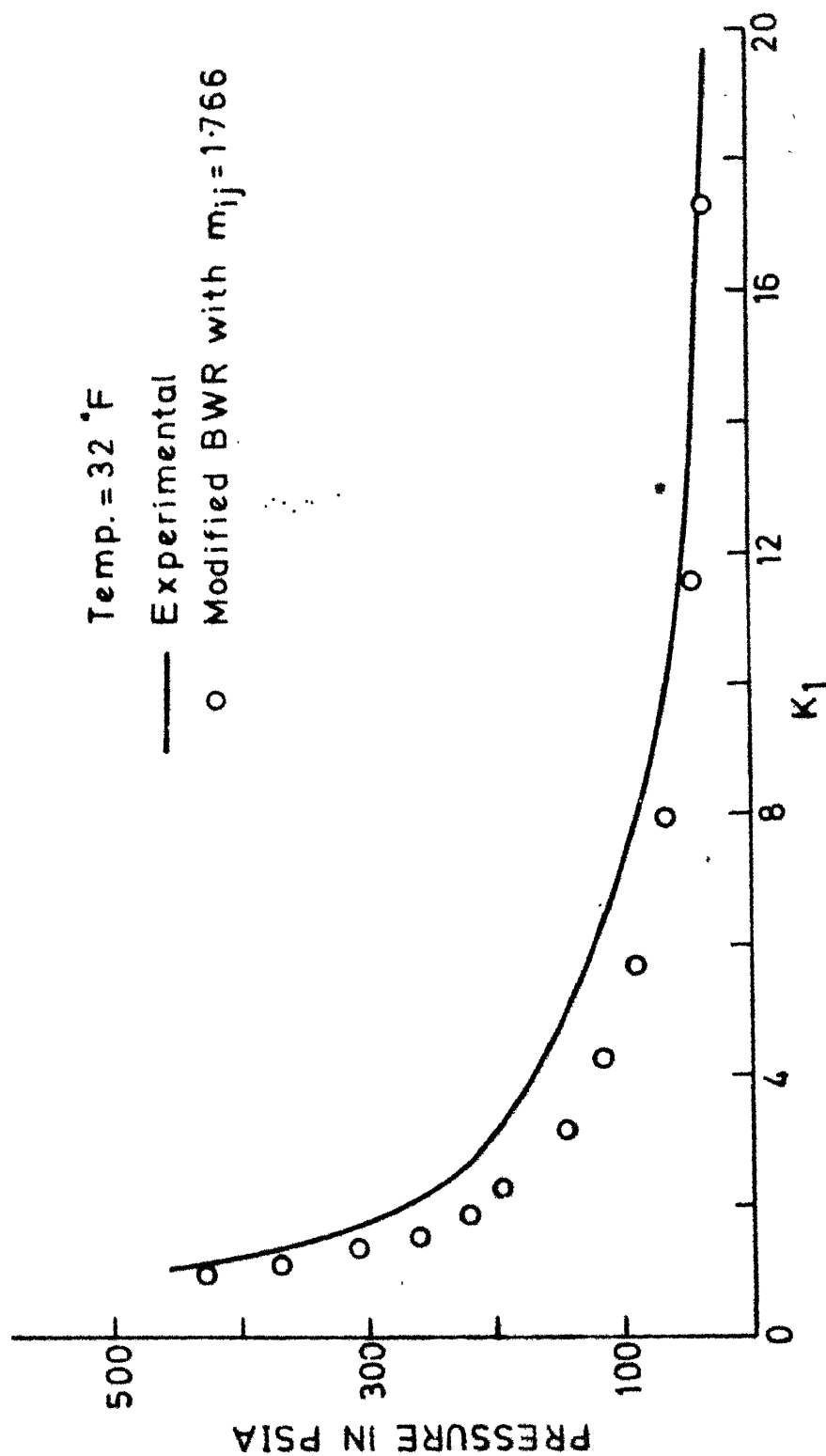


FIG.10 VAPORIZATION EQUILIBRIUM RATIO $K=y/x$ FOR CARBONDIOXIDE PROPANE MIXTURE

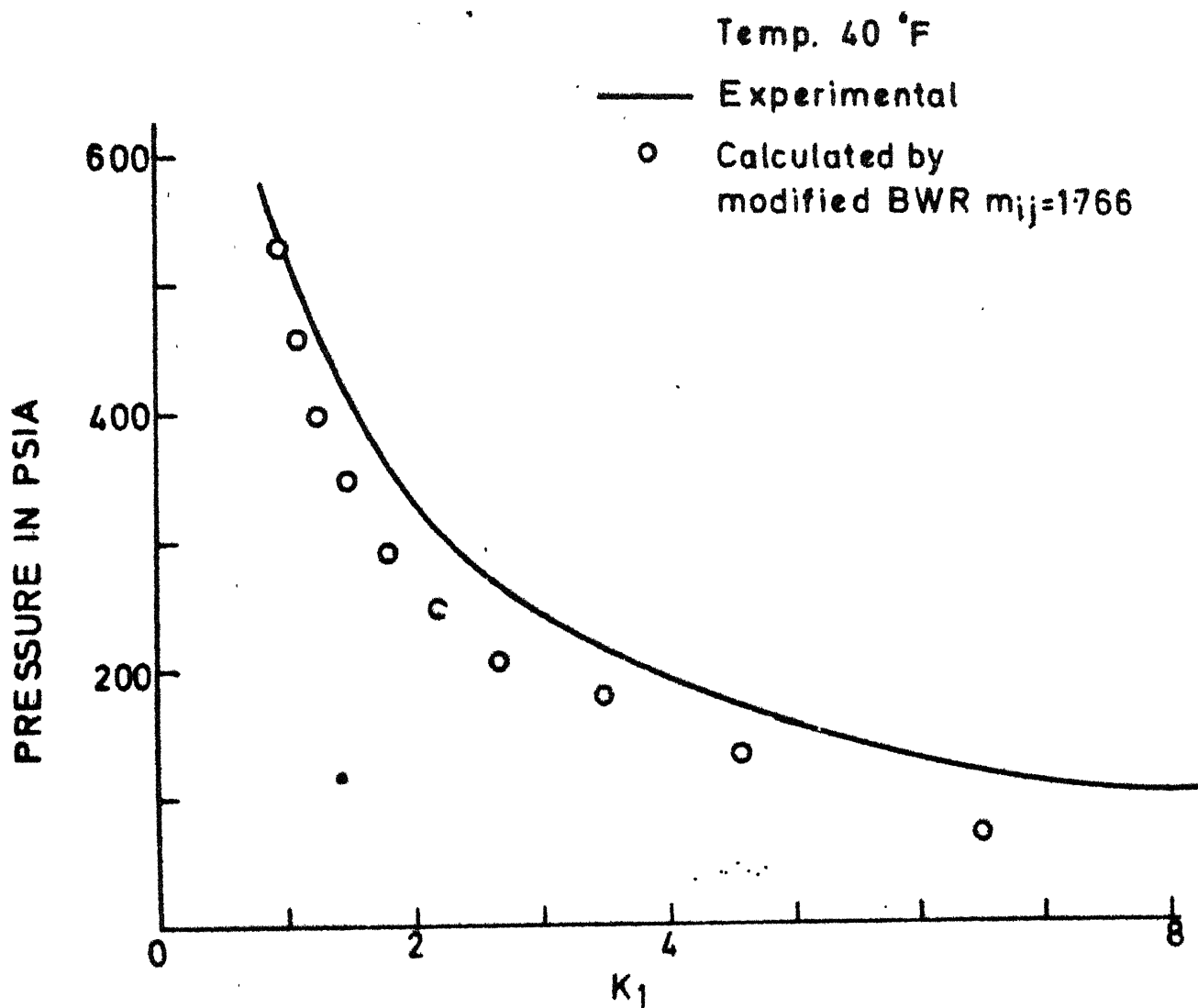


FIG.11 EQUILIBRIUM VAPORIZATION RATIO $K=y/x$ FOR $\text{CO}_2(1)$ -PROPANE MIXTURE

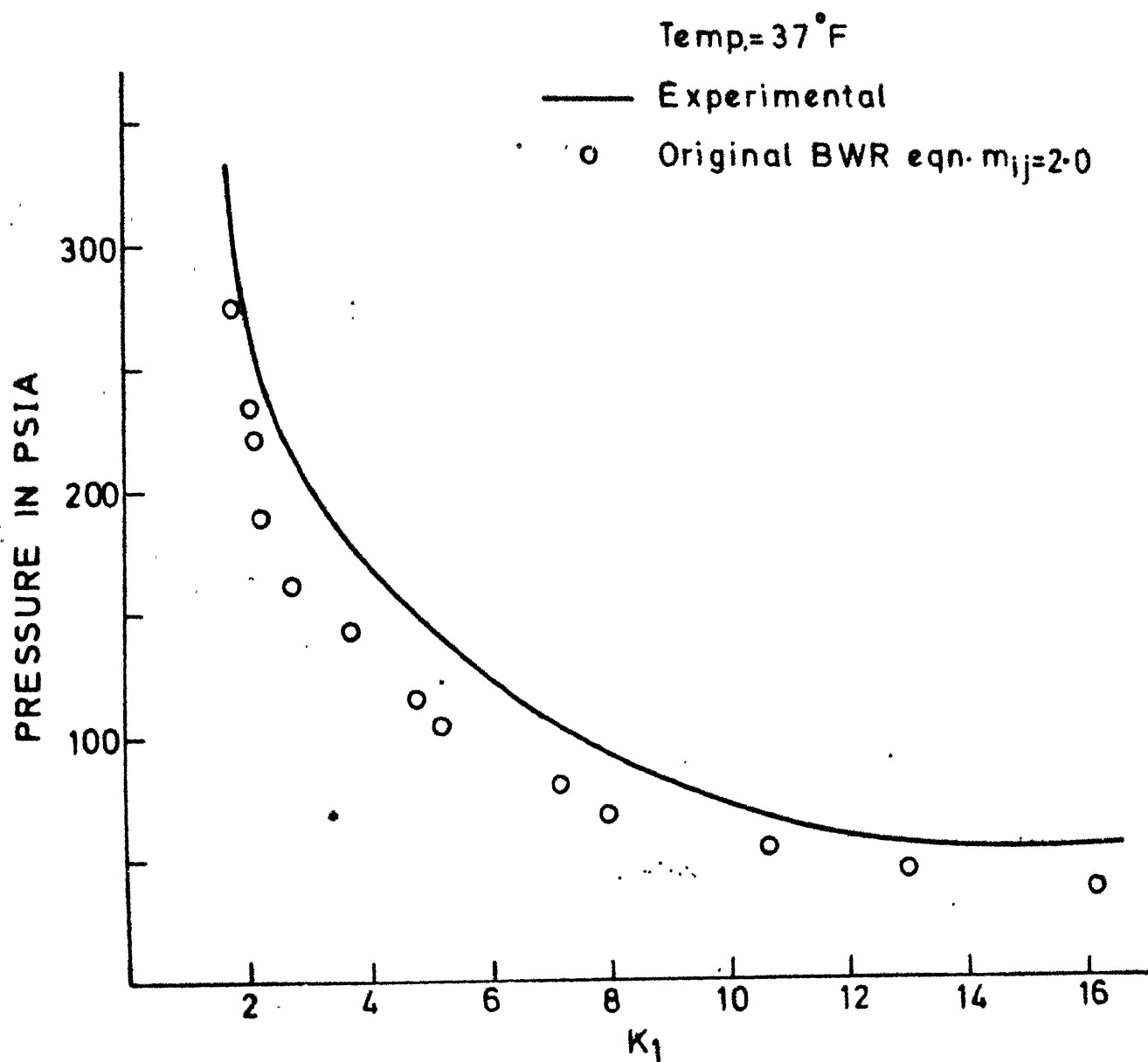


FIG. 12 EQUILIBRIUM VAPORIZATION RATIO FOR
CO₂-ISOBUTANE MIXTURE

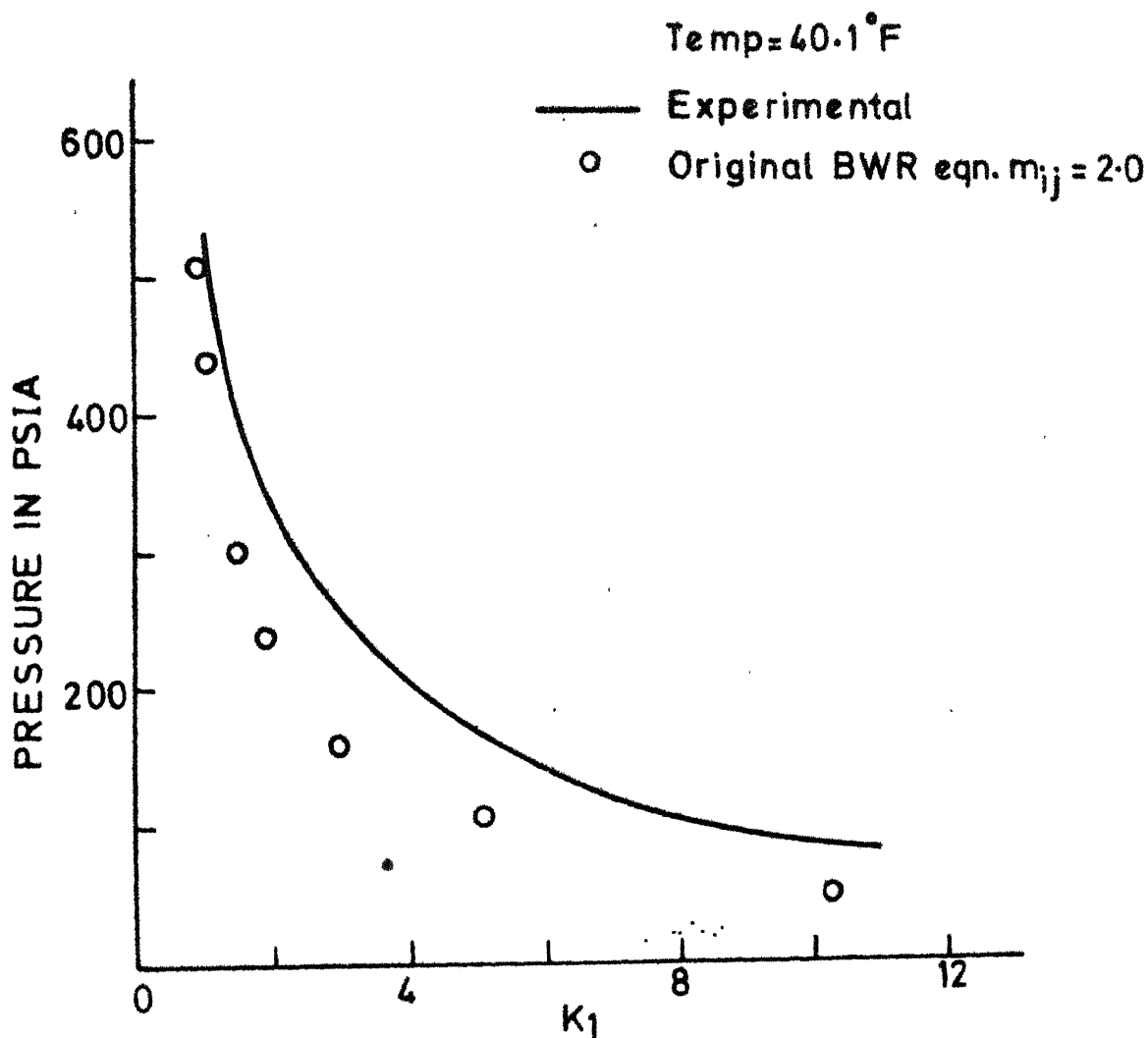


FIG. 13 EQUILIBRIUM VAPORIZATION RATIO $K=y/x$ FOR CO_2 -N PENTANE MIXTURE


```

100  C SCHEDULE 1 OF SIGMA THERM. TC. PRIP.
200  DIMENSION F(100), T(100)
300  CDP (UNIT=1, DEVISE='FSK', FILE='SIG. DAT')
400  READ(1,*) SIGMA
500  READ(1,*) EPSF
600  READ(1,*)(T(J), J=1,7)
700  PRINT 1
800  PRINT 2
900  PRINT 3
1000  T0=1000
1100  C=57 / FROD(1000)
1200  A=32.7
1300  Z=100 / A * (T(J)-32.7)+273.15 / EPSF
1400  F=0.0
1500  GO TO 20
1600  10  Z=FROD(1-1)*SIGP
1700  Y=Y*((SIGMA/Z)+12-(SIGMA/Z)*46)
1800  F0(T)=EXP(-X)
1900  20  T=100
2000  S=0.
2100  S=S+0.
2200  D=10 T=2.1 FV=2
2300  S=T=S0+1+F0(T)
2400  L=T+1
2500  IF(0.20,1) GO TO 30
2600  T=T+1
2700  30  F=F0(T)+F0(L)
2800  C=1.01+0.01*(T)
2900  D=1.0/Z+1.0+2+1.0+1+2+1+0.2)
3000  C=1.0
3100  C=1.0
3200  20  C=1.0/Z+1.0+2+1.0+1+2+1+0.2)
3300  40  C=1.0
3350  1  C=1.0/Z+1.0+2+1.0+1+2+1+0.2)
3375  2  C=1.0/Z+1.0+2+1.0+1+2+1+0.2)
3387  2  C=1.0/Z+1.0+2+1.0+1+2+1+0.2)
3400  *
3500  F=0.0

```



```

00100 TO FIND COMPR. FACTOR FOR MIXTURE
00200 DIMENSION TM(50),D1(50),D2(50),DM(50),RHU(50),XX(50),ZM(50)
00300 2,T(50)
00400 OPEN(UNIT=1,DEVICE='DSK',FILE='B5.DAT')
00500 READ(1,*) (D1(I),I=1,3)
00600 READ(1,*) (D2(I),I=1,3)
00700 READ(1,*) (DM(I),I=1,3)
00800 PRINT 1
00900 PRINT 2
01000 PRINT 3
01100 PRINT 9
01200 NDATA=0
01300 DENVIN=0.0
01400 DO 17 I=1,7
01500 READ(1,*) (C,(I=1,3),I=1,3)
01600 Y1=0.56
01700 Y2=1.-Y1
01800 PRINT 4,Y1
01900 PRINT 5,Y2
02000 P1=3.1428571
02100 P=P1*0.0685
02200 ZC1=0.271
02300 ZC2=0.2740
02400 ZC12=0.5*(ZC1+ZC2)
02500 TC1=334.2
02600 TC2=125.2
02700 TC12=0.955*(TC1+TC2)**0.5
02800 VC1=34.0
02900 VC2=255.0
03000 VC12=(1./3.)*(VC1**0.333+VC2**0.333)**3
03100 R=R2.057
03200 PC12=(ZC12*R*TC12)/0.125*(VC1**0.333+VC2**0.333)**3
03300 DM1=0.225
03400 DM2=0.193
03500 DM12=0.5*(DM1+DM2)
03600 AN=0.02322E+23
03700 RK=1.38044E-16
03800 A1=-5.851
03900 A2=-5.757
04000 A5=16.239
04100 A7=-5.966
04200 A27=-81.585
04300 C1=-1.27
04400 C2=7.438
04500 C3=-8.938
04600 C28=197.294
04700 DO 200 I=1,3
04800 C1=-1.27
04900 C2=7.438
05000 C3=-8.938
05100 A50=Y1**2*D1(I)**3+Y2**2*D2(I)**3+2.*Y1*Y2*((D1(I)+D2(I))/2
05200 2.)***3
05300 DM(I)=(A50)**0.333
05400 EPS1=195.20*1.38044E-16
05500 EPS2=223.74*1.38044E-16
05600 EPS3=(Y1*Y1*EPS1*(D1(I))**3+Y2*Y2*EPS2*(D2(I))**3+2.*Y1*Y2*
05700 2*(EPS1*EPS2)**0.5*((D1(I)+D2(I))/2.))**3)/(DM(I)**3)
05800 T(I)=(TM(I)-32.)*(5./9.)*273.16
05900 RHU(I)=P/(ZM(I)+R*T(I))
06000 X=P1*AN*(DM(I)**3)*RHU(I)/6.
06100 DO 60 J=1,7
06200 XX(J)=X**J
06300 60 CONTINUE
06400 RESULT=1.+4.*XX(1)+10.*XX(2)+18.*XX(3)+28.*XX(4)+19.*XX(5)
06500 2+5.*XX(6)-15.*XX(7)
06600 X=A*RHU(I)*(DM(I)**3)
06700 DO 70 I=1,29
06800 XX(J)=X**J
06900 70 CONTINUE
07000 BETA=EPS3/(T(I)*RK)
07100 RES11=RESULT+BETA*(A1*XX(1)+A2*XX(2)+A5*XX(5)+A7*XX(7)+
07200 2A27*XX(27))+BETA*BETA*(C1*XX(2)+C2*XX(3)+C3*XX(4)+C28*XX(29))
07300 TR1=T(I)/TC1
07400 TR2=T(I)/TC2
07500 TR12=T(I)/TC12
07600 F01=0.1445-0.33/TR1-0.1385/(TR1*TR1)-0.0121/(TR1**3)
07700 F02=0.1445-0.33/TR2-0.1385/(TR2*TR2)-0.0121/(TR2**3)
07800 F11=0.073+0.46/F01-0.5/(TR1*TR1)-0.097/(TR1**3)-0.0073/(TR1**8)
07900 F12=0.073+0.46/TR2-0.5/(TR2*TR2)-0.097/(TR2**3)-0.0073/(TR2**8)
08000 X1=F01+0.081+F11
08100 X2=F02+0.082+F12
08200 B1=X1*P*TC1/33.5
08300 B2=X2*P*TC2/37.47
08400 F012=0.1445-0.33/TR12-0.1385/(TR12*TR12)-0.0121/(TR12**3)
08500 F112=0.073+0.46/F012-0.5/(TR12*TR12)-0.097/(TR12**3)-
08600 0.0073/(TR12**8)
08700 F122=F012+0.0812+F112

```



```

09000 8*UJ=2.*PI*A1*(D*(T)**3)/3.+BETA*A1*A1*(DM(1)**3)
09100 E01=107.0852418-2444.3256915/TR1+53.469861915/(TR1**5)+
09200 2*(142.30301106+2439.3332920/TR1-57.379328503/(TR1**5))*
09300 2*(X57-1.17/10.)+(1.8129154482+1.1415112373/TR1)*(1.-
09400 2*E01*(1.7-11))*.1E-04
09500 F11=7312.7569893-166472.31956/TR1+2268.6104665/(TR1**5)
09600 2*(142.30301106+2439.3332920/TR1-57.379328503/(TR1**5))
09700 2*(X57-1.17/10.)+(1.8129154482+1.1415112373/TR1)*(1.-EXP(10./
09800 31011))*.1E-03
09900 F21=7312.7569893-166472.31956/TR1+2268.6104665/(TR1**5)+
10000 2*(142.30301106+2439.3332920/TR1-57.379328503/(TR1**5))*
10100 2*(X57-1.17/10.)+(1.8129154482+1.1415112373/TR1)*(1.-EXP(10./
10200 31011))*.1E-03
10300 C1=(F11+F21)/(1+0.0E1*OMF1*E21)*VC1*VC1
10310 S=1.-1.89*TR1*TR1
10320 Y=2.49-2.30*TR1+2.70*TR1*TR1
10330 FC=0.232*TR1*(-0.25)+0.468*TR1*(-5)*(1.-EXP(S))+
10340 23.0*EXP(-Y)
10350 C1=FC*VC1*VC1
10360
10370
10400
10500 S=1.-1.89*TR2*TR2
10600 Y=2.49-2.30*TR2+2.70*TR2*TR2
10700 FC=0.232*TR2*(-0.25)+0.468*TR2*(-5)*(1.-EXP(S))+
10800 22.*EXP(-Y)
10900 C2=FC*VC2*VC2
11000 S=2.5
11100 S=1.-1.89*TR12*TR12
11200 Y=2.49-2.30*TR12+2.70*TR12*TR12
11300 FC12=0.232*TR12*(-0.25)+0.468*TR12*(-5)*(1.-EXP(S))+
11400 22.*EXP(-Y)
11500 C12=(C1+C12*VC12)*.333
11600 C122=(C2+C12*VC12)*.333
11700 C2=(Y1**3)*(C1+C12*VC12)+12*C112+3.*C122*Y1*(12*Y2)+(12**3)*C2
11800 8*UJ=10.*(PI*A1*(D*(T)**3)/3.+BETA*A1*A1*(DM(1)**3)
11900 2*AN*(D*(T)**3)+BETA*A1*A1*(DM(1)**3)+BETA*A2*A2*(DM(1)**3)
12000 REST1=48501+(34-3*UJ)*RH0(I)
12100 REST2=2552+(C4-C*UJ)*RH0(I)*L(I)
12200 REST3=1.+(34*RH0(I)+C1*RH0(I))*L(I)
12300 REST5=10.*(REST1-Z4(I))/Z4(I)
12400 REST6=10.*(REST2-Z4(I))/Z4(I)
12500 REST7=10.*(REST3-Z4(I))/Z4(I)
12600 REST8=10.*(REST4-Z4(I))/Z4(I)
12700 NDATA=NDATA+1
12800 DEVI=DEVI+ABS(REST7)
12900 PRINT 5,T(I),Z4(I),REST1,REST2,REST3,REST7
13000 CONTINUE
13100 CONTINUE
13200 PRINT 9
13300 FORMAT(//4X, '-----')
13400 2
13500 AAD=DEVI/NDATA
13600 PRINT 10,AAD
13700 FORMAT(//,35X, 'Aver. Abs. Deviation, L=F8.4)
13800 1
13900 2
14000 2
14100 2
14200 2
14300 2
14400 5
14500 5
14600 STOP
14700 2

```


[illegible]

[illegible]


```

170 COMMON AK(10),X(10),Y(10),OMF(5),VC(5),TC(5),RHOC(5)
180 2,FCMB(5),FCVB(5),AO(5),BO(5),CO(5),A(5),B(5),C(5)
190 3,ALPH(5),GAM(5),AOM,BOM,COM,AM,BM,CM,ALPHM,GAMM
200 4,T,PT,PCOMP,XX(30),PP(30),YY(30),KK(30),NLAP
210 5,T0(5),O1(5),O2(5),O3(5),O4(5),TETA(5),DCO(5),COT(5)
220 BOM=0.0
230 COM=0.0; AM=0.0
240 BM=0.0; CM=0.0
250 ALPHM=0.0; GAMM=0.0
260 AOM=X(1)*X(1)*AO(1)+X(2)*X(2)*AO(2)+2.0*X(1)*X(2)
270 2*SORT(40(1)*AO(2))
280 DO 200 I=1,4COMP
290 BOM=BOM+Y(I)*BO(I)
300 COM=COM+Y(I)*SORT(CO(I))
310 AM=AM+Y(I)*A(1)**0.33333333
320 BM=BM+Y(I)*B(1)**0.33333333
330 CM=CM+Y(I)*C(1)**0.33333333
340 ALPHM=ALPHM+Y(I)*ALPH(I)**0.33333333
350 GAMM=GAMM+Y(I)*SORT(GAM(I))
360 COT=COT*COM
370 AM=AM**A**A
380 BM=BM**B**B
390 CM=CM**C**C
400 ALPHM=ALPHM*ALPHM*ALPHM
410 GAMM=GAMM*GAMM
420 MARKLV=2
430 CALL DEHS(RHO,P,MARKLV)
440 D=RHO
450 C
460 VAPOR PHASE FUGACITY COEFF.
470 TE10=GAMM*D*D
480 TE11=EXP(-TE10)
490 DO 200 I=1,4COMP
500 IF(1.E0,1)J=2
510 IF(1.E0,2)J=1
520 TE1=RT*ALOG(D*RT/P)
530 TE2=((BOM+BO(I))*RT-2.*SORT(COM*CO(I))/(T*T)-2.*Y(I)*AO(I)
540 2-1.766*Y(I)*SORT(AO(I)*AO(J)))*D
550 TE3=((3./2.)*(CM*BM*B(I))**((1./3.)*RT-(AM*AM*A(I))**
560 2(1./3.))*D*D
570 TE4=((3./5.)*(CM*(ALPHM*ALPHM*ALPH(I))**((1./3.))
580 2+ALPHM*(AM*AM*A(I))**((1./3.))*D**5
590 TE5=3.*(CM*CM*C(I))**((1./3.))*((1.-TE11)/TE10-TE11/2)
600 2*D*D/(T*T)
610 TE6=2.*(SORT(GAM(I)/GAMM))*((1.-TE11)/TE10-TE11-TE10*TE11/2)
620 2*CM*D*D/(T*T)
630 TE7=(TE1+TE2+TE3+TE4+TE5-TE6)/RT
640 FCMV(1)=EXP(TE7)
650 220
660 CONTINUE
670 RETURN
680 END
690 C
700 *****
710 SUBROUTINE DEHS(RHO,P,MARKLV)
720 COMMON AK(10),X(10),Y(10),OMF(5),VC(5),TC(5),RHOC(5)
730 2,FCMB(5),FCVB(5),AO(5),BO(5),CO(5),A(5),B(5),C(5)
740 3,ALPH(5),GAM(5),AOM,BOM,COM,AM,BM,CM,ALPHM,GAMM
750 4,T,PT,PCOMP,XX(30),PP(30),YY(30),KK(30),NLAP
760 5,T0(5),O1(5),O2(5),O3(5),O4(5),TETA(5),DCO(5),COT(5)
770 Z1=BOM*RT-AOM-COM/(T*T)
780 Z2=BM*RT-AM
790 Z3=AM*ALPHM
800 GO TO (3,4),MARKLV
810 3
820 CONTINUE
830 D=3.50
840 COP=0.05
850 DIFFE=0.50
860 300
870 IF(DIFFE-0.001)450,450,310
880 DO 350 J=1,400
890 D=D-COP
900 PCALC=RT*D+Z1*D*D+Z2*D*D+Z3*D**6+(CM*D*D*D/(T*T))*
910 2(1.0+GAMM*D*D)*EXP(-GAMM*D*D)
920 DIFE=P-PCALC
930 DIFE=ABS(DIFE)
940 IF(DIFE)350,330,330
950 330
960 GO TO 355
970 350
980 CONTINUE
990 355
1000 IF(COR-0.001)370,370,360
1010 D=D+COP
1020 COR=0.1*COP
1030 GO TO 300
1040 370
1050 CONTINUE
1060 450
1070 CONTINUE
1080 RHO=D
1090 GO TO 110
1100 C
1110 *****
1120 CONTINUE
1130 D=0.0

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26900
 27000
 27100 101
 27200 102
 27300
 27400
 27500
 27600
 27700 103
 27800 104
 27900 105
 28000 107
 28100 109
 28200
 28300
 28400 112
 28500
 28600 114
 28700

DIFF=1.0
 ZZ=0.0001
 IF(DIFF=ZZ) 112,112,102
 DO 100 J=1,400
 Z=Z+CUR
 PCALC=Z1*D+Z1*D*D+Z2*D*D*D+Z3*D**6+(CM*D*D*D/(T*T))*
 2*(1.0+GA*D*D*D)*EXP(-D**2)*D*D
 DIFF=P-PCALC
 DIFF=ABS(DIFF)
 IF(DIFF) 104,104,106
 GO TO 107
 CONTINUE
 IF(CUR=0.000000) 112,112,109
 D=D-CUR
 CUR=D.1*CUR
 GO TO 101
 CUSTIME
 PRINT
 PCTIME
 END